

Welding Codes & Standards

Sr. No.	Topic	Lecture (hrs.)
1	ASME Sec-IIA (Materials) ✓	3.00
2	ASME Sec-IIC (Welding Materials)	3.00
3	ASME Sec IX - WPQ	6.00
4	ASME Sec IX - WPS/PQR	6.00
5	ASME Sec VIII Div.1- Manufacturing ✓	7.00
6	ASME Sec VIII Div.2- Manufacturing	6.00
7	AWS - D1.1 - Structural	6.00
8	ASME B 31.3 - Piping	3.00



**ASME SEC. II-A - MATERIALS**


**Training Material for Welding Technology  
Programme for M.E. Students of  
The Maharaja Sayajirao University of Baroda-  
Varodara, sponsored by L&T.**


**LARSEN & TOUBRO LIMITED  
Heavy Engineering Division  
HAZIRA**








	<h1>ASME Boiler And Pressure Vessels Code</h1> <h2>Section-IIA</h2>	<p>By Allwyn Lewis</p>
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	<h1>Contents</h1> <ul style="list-style-type: none"> <li>■ Overview of various sections of ASME codes</li> <li>■ Material selection criteria.</li> <li>■ ASME Section II</li> <li>■ ASME Section IIA-Ferrous material specification</li> <li>■ Types of materials</li> <li>■ P' Numbers</li> <li>■ Specification for Carbon steel plate-SA 516/SA 516M</li> <li>■ Specification for Carbon steel forging</li> </ul>
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SECTIONS	
I	Rules for Construction of Power Boilers
II	Materials <ul style="list-style-type: none"> <li>Part A Ferrous Material Specification</li> <li>Part B Non-Ferrous Material Specification</li> <li>Part C Specifications for Welding rods, electrodes and Filler Metals</li> <li>Part D Properties (US Customary)</li> <li>Part D Properties (Metrics)</li> </ul>
III	Subsection NCA --- General Requirements for Division 1 & Division 2
III	Division 1
III	Division 2 ... Code for Concrete Reactor Vessels and Containments
III	Sub Section CC --- Concrete Containments
III	Division 3 ... Containment Systems for Storage and Transport
	Appendices
	Packaging of spent Nuclear Fuel and High level Radioactive Material and waste



## Code Cases

- In urgent need & when rules for materials/construction not covered by existing code rules
- Boiler and pressure vessel committee considers proposed addition and revision of codes & to formulate cases
- Adopted code case appears -2004 code case book
- (1) Boiler and pressure vessels
- (2) Nuclear components

A - 36 → C.M.T.M.  
SA 36 / A 36



## Addenda & Interpretations

- Colored sheet addenda-Includes addition & revisions to individual sections of code
- Published annually
- Sent automatically-Up to 2007 code publication
- Edition and addenda in loose leaf format
- As on today
- Edition 2004 & addenda 2006
- For interpretation of technical aspects -ASME issues written replies as interpretations
- Interpretations issued annually (July) with Edition/Addenda

## Material Selection Criteria



- > Service media
  - Corrosive-sea water, urea
  - $H_2H_2S$ , Ammonia
- > Temperature
  - Cryogenic
  - Low temperature
  - Medium temperature
  - High temperature
- > Pressure
  - Low pressure
  - High pressure - Q & T material

## Material Selection Criteria



- > Standard
  - Material specification
  - Additional requirements
- > Economy
  - Cost
  - Availability
  - Weldability
  - Manufacturability

## ASME Section II - Materials



- Part A - Ferrous material specifications
- ✗ ■ Part B - Non ferrous material specifications
- Part C - Specifications for welding rods, electrodes, and filler metals.
- ✗ ■ Part D - Properties (customary) Properties (metric)

## Section II Part A Ferrous Material Specification



Types

- Steel plates, sheets and strips for pressure vessels
- Steel pipes
- Steel tubes
- Steel flanges & fittings
- Structural Steel
- Steel bars
- Steel Bolting materials
- Steel forgings
- Corrosion-resisting and Heat-resisting steels

## Steel Plates

SA-20	General Requirements for Steel plates for Pressure Vessels
SA-203	Pressure Vessel Plates, Alloy steel, Nickel
SA-204	Pressure Vessel plates, Alloy steel, Molybdenum
SA-240	Chromium and Chromium-Nickel Stainless steel Plate, for Pressure vessel
SA-263	Corrosion-Resisting chromium steel-clad plate
SA-264	Stainless Chromium-Nickel-Steel Clad Plate
SA-265	Nickel and Nickel-Base Alloy Clad Steel Plate
SA-285	Pressure Vessel Plates, Carbon Steel
SA-302	Pressure Vessel Plates, Alloy Steel, Manganese-Molybdenum
SA-387	Pressure Vessel Plates, Alloy Steel, Chromium-Molybdenum

## Steel Plates

SA-480	General Requirements for Flat-Rolled Stainless Steel Plate
SA-515	Pressure vessel Plates, Carbon Steel, for Intermediate and Higher Temperature Service
SA-516	Pressure Vessel Plates, Carbon Steel, for Moderate and lower Temperature Service
SA-517	Pressure Vessel Plates, Alloy Steel, High Strength, Quenched and Tempered
SA-533	Pressure Vessel Plates, Alloy Steel, Quenched And Tempered, Manganese-Silicon Steel
SA-537	Pressure Vessel Plates, Heat Treated, Carbon-Manganese-Silicon Steel
SA-542	Pressure Vessel Plates, Alloy steel, quenched and Tempered, Chromium-Molybdenum

Steel Pipes	
>	SA-106 Seamless Carbon Steel Pipe for High Temperature
>	SA-312 Seamless and Welded Austenitic Stainless Steel Pipes
>	SA-333 Seamless and Welded Steel Pipe for Low-Temperature Service
>	SA-335 Seamless ferritic Alloy Steel Pipe for High Temperature Service
>	SA-999 General requirements for alloy and Stainless Steel Pipe

Steel Tubes	
>	SA-179 Seamless Cold-Drawn low-carbon steel Heat Exchanger and condenser Tubes
>	SA-213 Seamless Ferritic and Austenitic Alloy-Steel Boiler, Superheater, and Heat Exchanger Tubes
>	SA-450 General requirements for Carbon, Ferritic Alloy, and Austenitic Alloy Steel Tubes.
>	SA-1016 General Requirements for Ferritic Alloy, and Austenitic Alloy Steel, and Stainless Steel Tubes.

## Steel Flanges and Fittings

SA-105	Carbon Steel Forgings, for Piping Applications
SA-181	Carbon Steel Forgings, for General-Purpose Piping
SA-182	Forged or Rolled Alloy-Steel Pipe Flanges, Forged Fittings, for High-Temperature Service
SA-234	Piping Fittings of carbon steel and alloy for moderate and high-temperature service
SA-350	Carbon and low-alloy steel forgings, requiring notch toughness testing for piping components
SA-403	Wrought austenitic stainless steel piping fittings
SA-420	Piping fittings of wrought carbon steel and alloy steel for low-temperature service
SA-960	Common requirements for wrought steel piping fittings
SA-961	Common requirements for steel flanges, forged fittings

## Structural Steel

SA-6	General Requirements for Rolled Structural Steel Bars, Plates, Shapes and Sheet Piling
SA-36	Carbon Structural Steel
SA-283	Low and intermediate tensile strength carbon steel plate



Steel Bolting	
>	SA-193 Alloy Steel and Stainless Steel Bolting Material for High-Temperature Service
>	SA-194 Carbon and alloy Steel Nuts for Bolts for High-Pressure and High Temperature Service
>	SA-320 Alloy steel Bolting Materials for Low-Temperature Service
>	SA-962 Common Requirements for Steel Fasteners or Fastener Materials or Both, Intended for Use at any temperature from Cryogenic to the Creep Range

Steel Forgings	
>	SA-105 Carbon Steel Forgings, for Piping Applications
>	SA-181 Carbon Steel Forgings, for General Purpose Piping
>	SA-266 Carbon Steel Forgings, for Pressure Vessel Components
>	SA-366 Alloy Steel Forgings for Pressure and High-Temperature Parts
>	SA-350 Carbon and Low-Alloy Steel Forgings, Requiring Notch Toughness Testing for Piping components
>	SA-508 Quenched and Tempered Vacuum-Treated Carbon and Alloy Steel Forgings for Pressure Vessels
>	SA-541 Quenched and Tempered Carbon and Alloy Steel Forgings for Pressure Vessel Components
>	SA-788 Steel Forgings, General Requirements

# DIFFERENT P NUMBERS P1 # P9



## Testing Methods

>	SA-275	Magnetic Particle Examination of Steel Forgings
>	SA-370	Test methods and definitions for mechanical testing of Steel Products
>	SA-388	Ultrasonic Examination of heavy steel Forgings
>	SA-435	Straight-beam ultrasonic Examination of Steel Plates
>	SA-577	Ultrasonic angle beam examination of Steel Plates
>	SA-578	Straight beam ultrasonic Examination of Plain and clad steel plates for special applications.
>	SA-945	Ultrasonic Examination of austenitic steel forgings
>	SA-751	Test methods, practices and terminology for chemical analysis of Steel Products



P3				
P. No	Group No	Mat. Spec.	Grade	Met. Quality & Form
P3	2	SA 302	A	Mn - 0.5 Mo - Plate
P3	3	SA 302	B,C,D	Mn - 0.5 Mo - Plate
P3	1	SA 335	P1 / P2	C - 0.5 Mo - Pipe
P3	3	SA 533	TP-R, CL-1 or 2	C - 0.5 Mo - Plate
P3	1	SA 209	T1, T1a, T1b	C - 0.5 Mo - Tube
P3	2	SA 282	F1	C - 0.5 Mo - Forging

P1				
P. No	Group No	Mat. Spec.	Grade	Met. Quality & Form
P1	1	SA 515 / SA 516	60	CS - Plate
P1	2	SA 515 / SA 516	70	CS - Plate
P1	1	SA 106	A / B	CS - Pipe
P1	2	SA 106	C	CS - Pipe
P1	1	SA333	6	CS - Pipe
P1	3	SA 333	10	CS - Pipe
P1	1	SA 234	WPB	CS Pipe Fitting
P1	2	SA 234	WPC	CS Pipe Fitting
P1	1	SA 285	C / B	CS Plate
P1	1	SA 179	---	CS Tube
P1	1	SA 105	---	CS Forging
P1	2	SA 181	CI 70	CS Forging



## P5A/B/C

P. No	Group No	Mat. Spec.	Grade	Met. Quality & Form
P5A	1	SA 387	22, CI-1 / 2	2.25 Cr. 1 Mo - Plate
P5B	1	SA 387	5, CI-2	5 Cr. 0.5 Mo - Plates
P5A	1	SA 335	P22	2.25 Cr. 1 Mo - Pipe
P5A	1	SA 213	TP-22	2.25 Cr. 1 Mo - Tube
P5B	1	SA 182	F5	5 Cr - 0.5 Mo - Forging
P5C	1	SA 182	F22V	2.25 Cr - 1 Mo, V - Forging
P5A	1	SA 336	F22, CI-1 / 3	2.25 Cr - 1 Mo - Forging



## P4

P. No	Group No	Mat. Spec.	Grade	Met. Quality & Form
P4	1	SA 387	12, CI-1 / 2	1Cr. 0.5 Mo - Plate
P4	3	SA 387	11, CI-1 / 2	1.25 Cr. 0.5 Mo - Plate
P4	1	SA 335	P12 / P11	1Cr (1.25 Cr) - 0.5 Mo - Pipe
P4	2	SA 423	TP-1 / 2	1.25 Cr. 0.5 Mo - Tube
P4	1	SA 282	F12, CI-1 / 2	1. Cr - 0.5 Mo - Forging
P4	1	SA 336	F11, CI-1 / 2 / 3	1.25 Cr - 0.5 Mo - Forging



## P8


P. No	Group	Mat. Spec.	Grade	Met. Quality & Form
P8	1	SA 312	TP321	18Cr, 10Ni, Ti - Pipe
P8	1	SA 312	TP347	18Cr, 10Ni, Nb - Pipe
P8	1	SA 336	TP316	18Cr, 8 Ni, 2Mo - Forging
P8	1	SA 336	TP310	25Cr, 20 Ni, Forging
P8	1	SA 240	TP304	18Cr, 8Ni - Plates
P8	2	SA 204	TP309S	23Cr, 12Cr - Plates
P8	1	SA 249	TP317	18Cr, 13Ni, 3Mo - Tube
P8	1	SA 249	TP316L	16Cr, 12Ni, 2Mo - Tube



## P6&7

P. No	Group	Mat. Spec.	Grade	Met. Quality & Form
P6	2	SA 240	TP 429	15Cr - Plate
P6	4	SA 731	S41500	13Cr, 4.5 Ni, Mo - Pipe
P6	1	SA 268	TP410	13Cr - Tube
P6	3	SA 336	F6	13Cr - Forging
P7	2	SA182	F430	17Cr - Forging
P7	2	SA 240	TP 430	17Cr - Plate
P7	2	SA 268	TP430	17Cr Tube
P7	2	SA 731	TP439	18Cr, Ti - Pipe

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		P9AB			
P. No	Grou p No	Mat. Spec.	Grade	Met. Quality & Form	
P9B	1	SA 333	3	3.5Ni - Pipe	
P9A	1	SA334	7	2.5Ni - Tube	
P9A	1	SA 350	LF5, Cl. 2	1.5Ni - Forging	
P9B	1	SA 350	LF3	3.5Ni - Forging	
P9A	1	SA 203	A	2.5Ni - Plate	
P9B	1	SA 203	E	3.5Ni - Plate	

Scope											
<ul style="list-style-type: none"> <li>Carbon steel plates – Welded pressure vessels with improved notch toughness</li> <li>Grades under this specification:</li> </ul>											
<table> <tr> <th>Tensile Strength Ksi (MPa)</th><th>Grade U.S.(SI)</th></tr> <tr> <td>55-75 (380-515)</td><td>55 (380)</td></tr> <tr> <td>60-80 (415-550)</td><td>60 (415)</td></tr> <tr> <td>65-85 (450-585)</td><td>65 (450)</td></tr> <tr> <td>70-90 (485-620)</td><td>70 (485)</td></tr> </table>	Tensile Strength Ksi (MPa)	Grade U.S.(SI)	55-75 (380-515)	55 (380)	60-80 (415-550)	60 (415)	65-85 (450-585)	65 (450)	70-90 (485-620)	70 (485)	
Tensile Strength Ksi (MPa)	Grade U.S.(SI)										
55-75 (380-515)	55 (380)										
60-80 (415-550)	60 (415)										
65-85 (450-585)	65 (450)										
70-90 (485-620)	70 (485)										
<ul style="list-style-type: none"> <li>Maximum thickness of the plates furnished (To meet specified mechanical property requirements)</li> </ul>											
<table> <tr> <th>Maximum thickness, in. (mm)</th><th>Grade U.S.(SI)</th></tr> <tr> <td>12 (305)</td><td>55 (380)</td></tr> <tr> <td>8 (205)</td><td>60 (415)</td></tr> <tr> <td>8 (205)</td><td>65 (450)</td></tr> <tr> <td>8 (205)</td><td>70 (485)</td></tr> </table>	Maximum thickness, in. (mm)	Grade U.S.(SI)	12 (305)	55 (380)	8 (205)	60 (415)	8 (205)	65 (450)	8 (205)	70 (485)	
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12 (305)	55 (380)										
8 (205)	60 (415)										
8 (205)	65 (450)										
8 (205)	70 (485)										

General Requirements	
<ul style="list-style-type: none"> <li>Material specification conforming to SA 20/ SA 20M outlining</li> <li>Testing and retesting methods and procedures</li> <li>Permissible variation in dimensions and mass</li> <li>Quality and repair of defects</li> <li>Marking, loading etc.</li> <li>Establishes rules for ordering information</li> <li>Additional Requirements - Supplementary Requirements</li> <li>Vacuum Treatment</li> <li>Additional tension testing</li> <li>Impact testing</li> <li>Non destructive examination</li> <li>In case of conflict with SA 20/SA 20M - Requirement of this specification prevails</li> </ul>	

## Manufacture & Heat Treatment

- Steel making practice  
Killed steel  
Fine austenitic grain size-As per SA 20/SA 20M
- Heat treatment conditions as per thickness  
< 40 mm – As rolled condition/Normalized or stress relieved or both (without notch toughness requirements)  
< 40 mm – Normalized (with notch toughness requirements)  
> 40 mm – Normalized
- Faster cooling rates are permissible – For toughness improvement – Provided plates are tempered (595 - 705°C)

## Chemical Requirement

TABLE 1  
CHEMICAL REQUIREMENTS

Composition, %			
Grade 55 (Grade 380)	Grade 60 (Grade 415)	Grade 65 (Grade 450)	Grade 70 (Grade 485)
Carbon, max <sup>a</sup>			
0.18	0.23	0.26	0.28
<sup>b</sup> / <sub>2</sub> in. (12.5 mm) and under			
0.20	0.25	0.28	0.30
Over <sup>b</sup> / <sub>2</sub> in. to 2 in. (12.5 to 50 mm), incl			
0.22	0.27	0.29	0.31
Over 2 in. to 4 in. (50 to 100 mm), incl			
0.24	0.27	0.29	0.31
Over 4 to 6 in. (100 to 200 mm), incl			
0.26	0.27	0.29	0.31
<sup>b</sup> / <sub>2</sub> in. (12.5 mm) and under:			
Heat analysis <sup>c</sup>			
0.60-0.90	0.60-0.90	0.65-1.20	0.85-1.20
Product analysis <sup>d</sup>			
0.55-0.96	0.55-0.96	0.79-1.30	0.79-1.50
Over <sup>b</sup> / <sub>2</sub> in. (12.5 mm)			
Heat analysis			
0.60-1.20	0.65-1.20	0.85-1.20	0.85-1.20
Product analysis			
0.55-1.30	0.79-1.30	0.79-1.30	0.79-1.30
Phosphorus, max <sup>e</sup>			
0.035	0.035	0.035	0.035
Sulfur, max <sup>f</sup>			
0.035	0.035	0.035	0.035
Silicon:			
Heat analysis			
0.15-0.40	0.15-0.40	0.15-0.40	0.15-0.40
Product analysis			
0.13-0.45	0.13-0.45	0.13-0.45	0.13-0.45

<sup>a</sup> Applies to both heat and product analysis.  
<sup>b</sup> Grade 60 plates <sup>b</sup>/<sub>2</sub> in. (12.5 mm) and under in thickness may have 0.85-1.20% manganese on heat analysis, and 0.79-1.30% manganese on product analysis.



## 7 Other Supplementary Requirements


- Vacuum treatment
- Product analysis
- Simulated PWT of mechanical test coupons
- Additional tension test
- Charpy V-notch impact test
- High-Temperature tension test
- Ultrasonic examination
- Magnetic particle examination
- Bend test


## 7 Mechanical Requirements

TABLE 2  
TENSILE REQUIREMENTS

Grade		Tensile strength, ksi (MPa)		Yield strength, min. <sup>a</sup> ksi (MPa) <sup>2</sup>		Elongation in 2 in. (50 mm), min., %		Elongation in 5 in. (125 mm), min., %	
55 (380)	60 (415)	60-80 (415-550)	45-65 (450-505)	70-90 (485-620)	38 (260)	23 <sup>d</sup>	27 <sup>d</sup>	23 <sup>d</sup>	25 <sup>d</sup>
70 (485)	65 (450)				35 (240)	19 <sup>d</sup>	25 <sup>d</sup>	19 <sup>d</sup>	23 <sup>d</sup>

<sup>a</sup> See Specification A 204/A 20M.  
<sup>b</sup> Determined by either the 0.2% offset method or the 0.5% extension-under-load method.

	<h2 data-bbox="751 958 900 1014">Scope</h2> <ul style="list-style-type: none"> <li>■ For ambient &amp; high temperature service-Pressure systems</li> <li>■ Forging includes – flanges, fittings and valves</li> <li>■ Maximum weight of forging -4540 Kg</li> <li>■ <u>&gt; 4540 kg-Order as per SA 266</u></li> <li>■ Tube sheet-Not included in this scope</li> <li>■ Supplementary requirements provided for additional testing-When specified by the purchaser</li> </ul>
---	--


	<h2 data-bbox="427 1541 1182 1720">Specification for Carbon Steel Forgings for Piping Applications (SA-105/SA-105M)</h2>	
---	--	--

## Ordering Information

- Purchase order should include as a minimum
  - Quantity
  - Size & dimensions
  - Specification number
  - Supplementary requirements
  - Additional requirements


## Materials and Manufacture

- Method of steel making
  - Open hearth furnace
  - Basic oxygen furnace
  - Electric furnace
- Fully killed Steel
- Sufficient discard-Avoiding injurious piping & undue segregation
- Material forged - To specified shape and size
- For hollow cylindrical part machined from hot rolled bar-Axial length to be parallel to metal flow line of the stock




## Annealing

- Immediately after forging operation Cool the forging – temperature below 538°C
- Re-heat to a temperature 843 - 927°C - to refine the grain
- A group of forging re-heated represents-Annealing charge
- Uniformly cool in the furnace




## Heat Treatment

- Not a mandatory requirement except for  
Flanges above class 300  
Special design flanges-exceeding pressure temperature rating of class 300
- Flanges - Unknown design temperature or pressure  
Piping component-Over NPS 4 & above class 300
- Applicable Heat treatment are  
Annealing  
Normalizing  
Normalizing and tempering  
Quenching and tempering



## Tempering

- Tempering temperature-593°C to lower transformation temperature
- Tempering time-0.5hr/in (min) of maximum section thickness



## Normalizing

- Immediately after forging operation Cool the forging - temperature below 538°C
- Re-heat to a temperature 843 - 927°C - to refine the grain
- A group of forging re-heated represents-Normalizing charge
- Uniformly cool in the air

# Chemical Composition



TABLE 1  
CHEMICAL REQUIREMENTS

Element	Composition, %
Carbon	0.35 max
Manganese	0.60-1.05
Phosphorus	0.035 max
Sulfur	0.040 max
Silicon	0.10-0.35
Copper	0.40 max (Note 1)
Nickel	0.40 max (Note 1)
Chromium	0.30 max (Notes 1)(2)
Molybdenum	0.12 max (Notes 1)(2)
Vanadium	0.05 max
Columbium	0.02 max

General Note—For each reduction of 0.01% below the specified carbon maximum (0.35%), an increase of 0.06% manganese above the specified maximum (1.05%) will be permitted up to a maximum of 1.35%.

NOTES:  
(1) The sum of copper, nickel, chromium and molybdenum shall not exceed 1.00%.  
(2) The sum of chromium and molybdenum shall not exceed 0.32%.

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# Quenching



- First procedure
- Forging fully austenitized
- Quenched in suitable liquid medium
- Multiple stage procedure
- Forging fully austenitized
- Rapidly cooled
- Re-heat to partially re-austenitize
- Quenching in suitable liquid medium
- All quenched forgings to be tempered

## Cast or Heat Analysis

- For analysis - Samples taken during pouring of heat

TABLE 1  
CHEMICAL REQUIREMENTS

Element	Composition, %
Carbon	0.35 max
Manganese	0.60-1.05
Phosphorus	0.025 max
Sulfur	0.040 max
Silicon	0.10-0.35
Copper	0.40 max (Note (1))
Nickel	0.40 max (Note (1))
Chromium	0.30 max (Notes (1) & (2))
Molybdenum	0.12 max (Notes (1) & (2))
Niobium	0.05 max
Columbium	0.02 max

General Note—For each reduction of 0.01% below the specified carbon maximum (0.35%), an increase of 0.05% manganese above the specified maximum (1.05%) will be permitted up to a maximum of 1.55%.

### NOTES:


- (1) The sum of copper, nickel, chromium and molybdenum shall not exceed 1.00%.
- (2) The sum of chromium and niobium shall not exceed 0.32%.


## Product Analysis

- For solid forgings-sample taken midway between center and surface
- For hollow forging-sample taken midway between inner surface and outer surface
- Sample for analysis can also be taken from broken mechanical test specimen





 <h2 data-bbox="655 902 1027 952">Hardness Test</h2>	<ul style="list-style-type: none"> <li>■ Minimum of two forgings required to be tested per batch</li> <li>■ Hardness range-137 – 187 HB inclusive.</li> </ul>
--	---

 <h2 data-bbox="563 1798 1129 1848">Mechanical Properties</h2>	<ul style="list-style-type: none"> <li>■ Specimens taken from production forging after heat treatment</li> <li>■ Specimens taken from separately forged test blanks prepared from same stock</li> <li>■ Test blank should have</li> <li>■ Approximately same working as product</li> <li>■ Heat treatment with finished product</li> <li>■ For N, N+T, Q+T- Central axis of test specimen at 1/4 T or deeper</li> <li>■ <u>Tension Test</u></li> <li>■ For each heat-one test</li> <li>■ More then one heat in a heat treating charge-one test per heat</li> <li>■ Same heat treating temperature and furnace with +/- 14°C-equipped with recording pyrometers-one tension test per heat</li> </ul>
---	---

## Repair by Welding

- Repair of defects permissible for forgings made to dimensional standard
- Prior approval of purchaser required-special forgings
- Welding procedure and welder-qualified as per ASME sec. IX
- Welding process with high level of hydrogen-not permissible
- Before welding-MT of ground area
- Forgings repair welding-to be PWHT
- Without prior approval of purchaser-repair shall not exceed 10% of surface area
- 33% of wall thickness
- 10 mm, Which ever is lesser.




**ASME SEC. II-C -  
WELDING MATERIALS**

**Training Material for Welding Technology  
Programme for M.E. Students of  
The Maharaja Sayajirao University of Baroda-  
Varodara, sponsored by L&T.**

**LARSEN & TOUBRO LIMITED  
Heavy Engineering Division  
HAZIRA**
















# ASME SEC II C

Deals with specification for :









- Welding Rods
- Welding Electrode
- Filler metals
- Welding Flux




# A Presentation on ASME SECTION II C

By Allwyn Lewis














## ASME SEC II C

> Deals with specification for :









- Welding Rods
- Welding Electrode
- Filler metals
- Welding Flux
































## AWS Specification

SAW	FCAW	GMAW/ GTAW	CS	SS	LAS	Ni	Al
A5.17	A5.20	A5.18	A5.4	A5.5	A5.11	A5.3	-
A5.9	A5.22	A5.28	A5.14	A5.10	-	-	-

	<b>AWS Specification</b>	
	➤ SFA-5.01 : Filler Metal Procurement Guideline	
	➤ SFA-5.12 : Tungsten & Tungsten-alloy Electrode for Arc Welding & Cutting.	
	➤ SFA-5.13 : Surfacing Electrode for SMAW	
	➤ SFA-5.15 : Welding Electrodes & Rods for Cast Iron	
	➤ SFA-5.21 : Bare Electrodes & Rods for Surfacing.	
	➤ SFA-5.16 : Titanium & Titanium Alloy Welding Electrodes & Rods	
	➤ SFA-5.7 : Copper & Copper Alloy Bare Welding rods & Electrodes.	

	<b>AWS Classification For Stick Electrode (CS)</b>	
		
		
		
		
		
		
		
		
		

YZ : Together indicate polarity

Type of covering

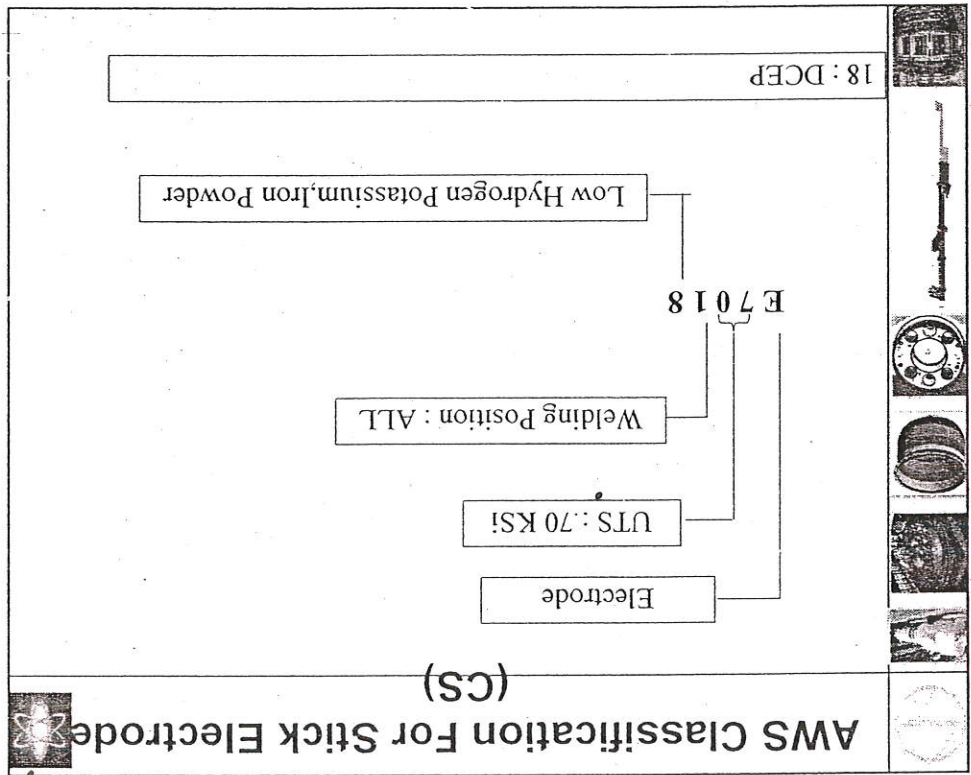
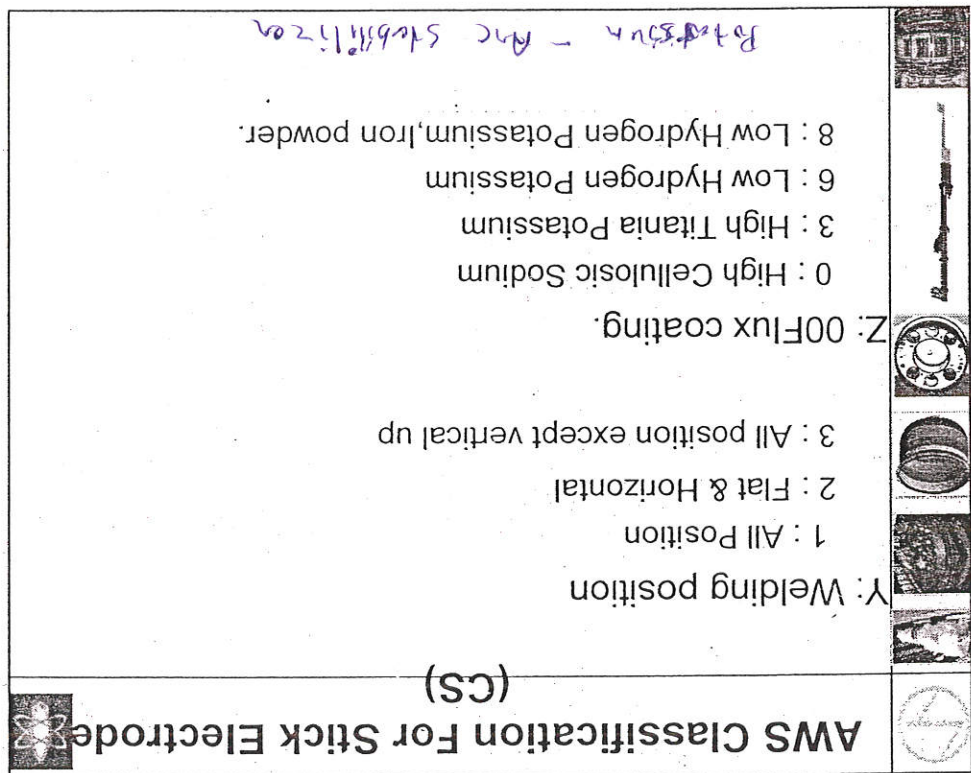
E XX Y Z

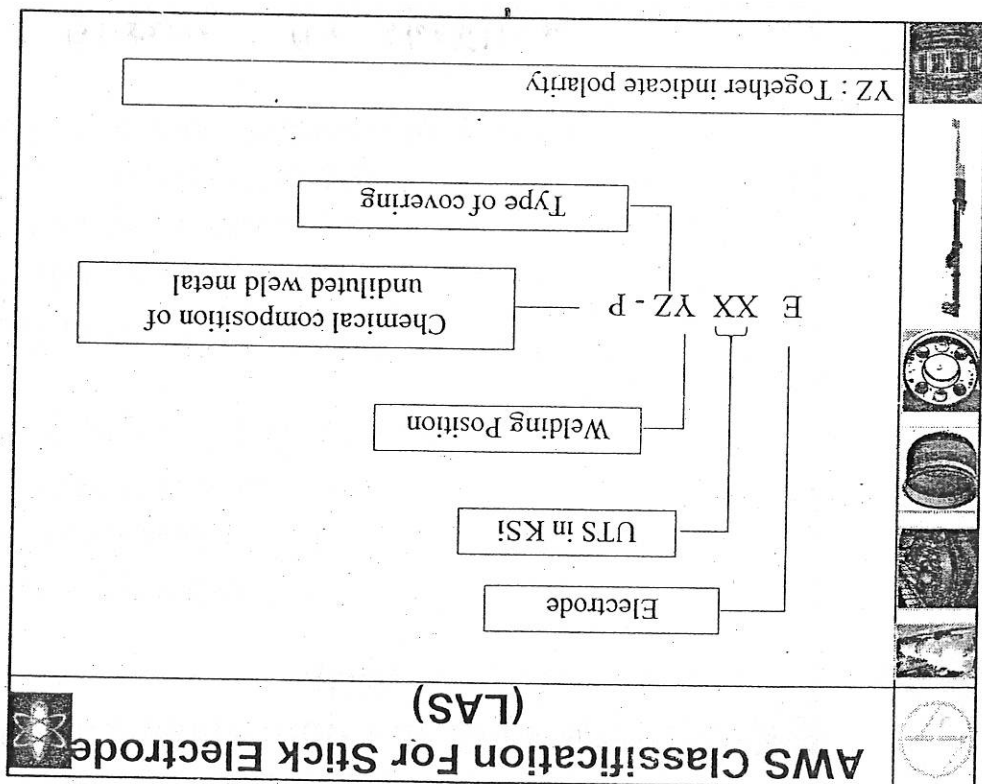
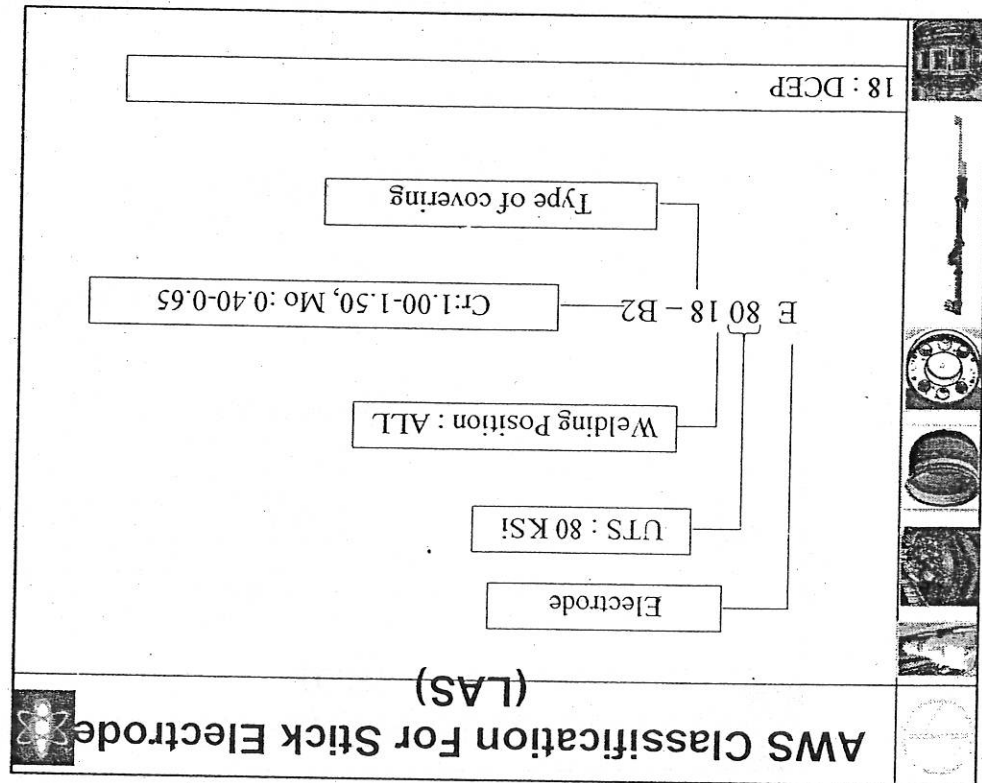
Welding Position

UTS in KSI

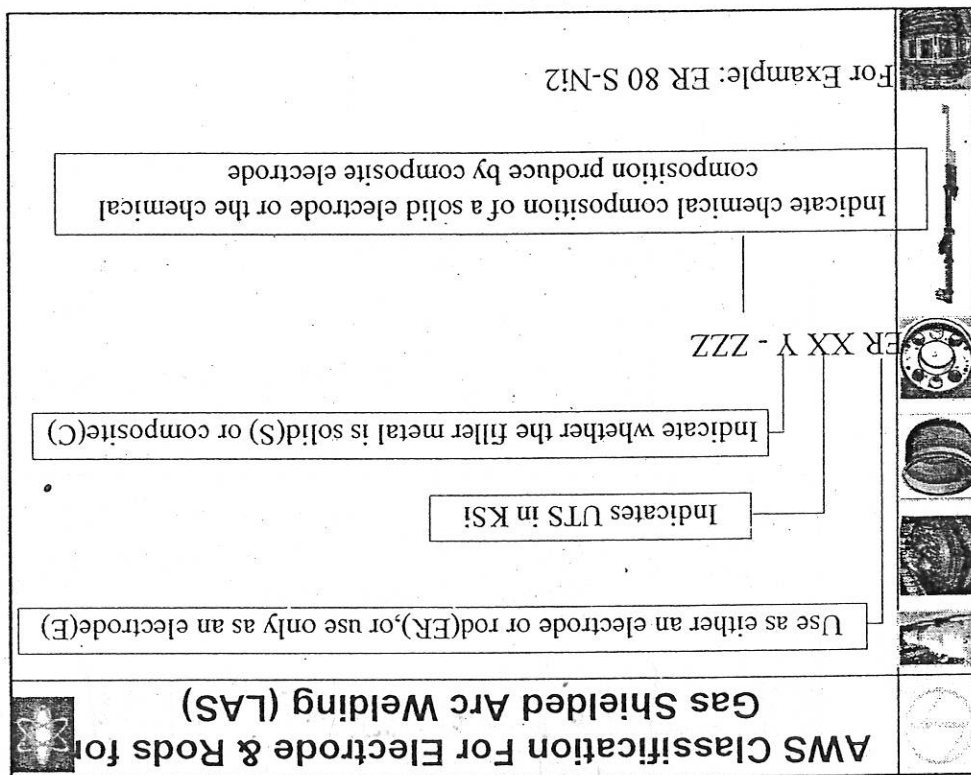
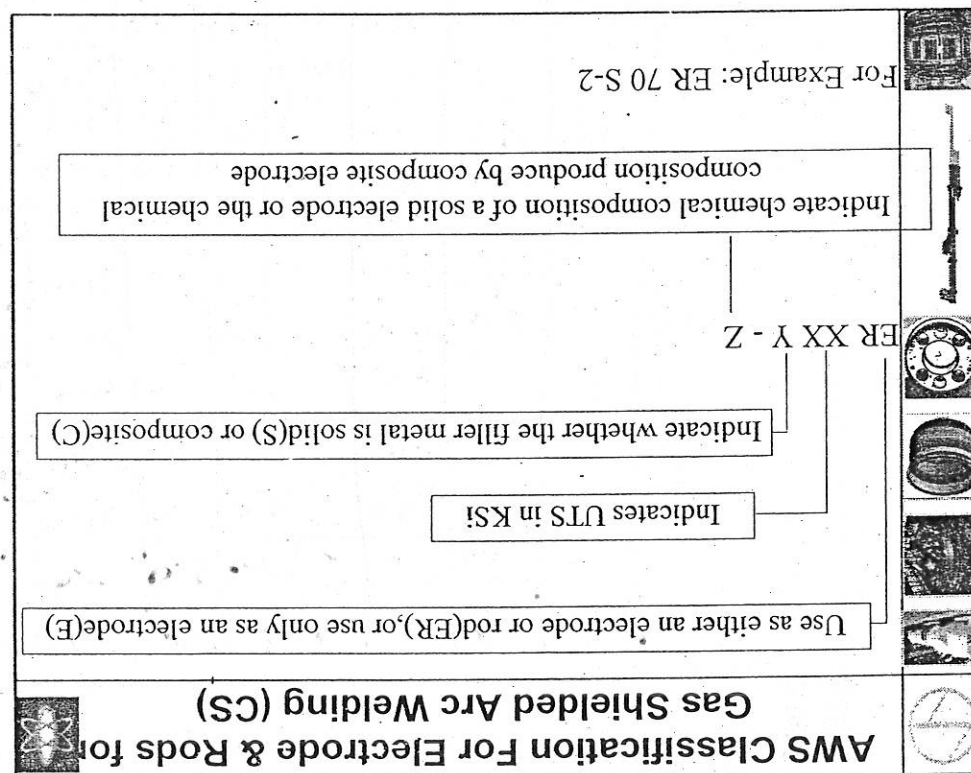
Electrode



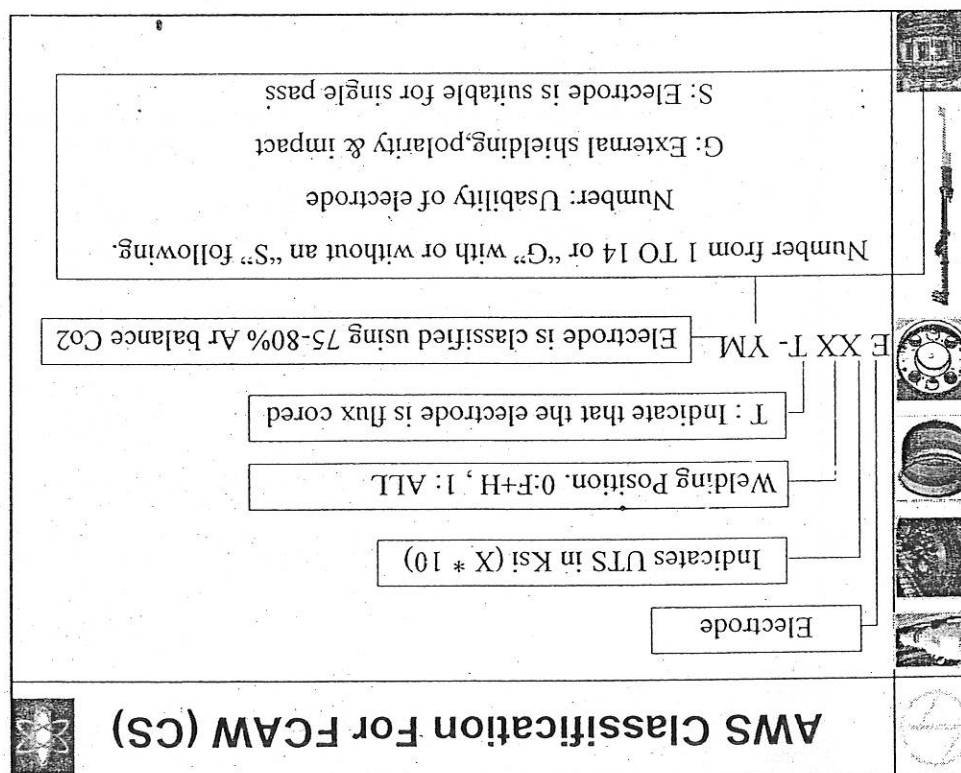
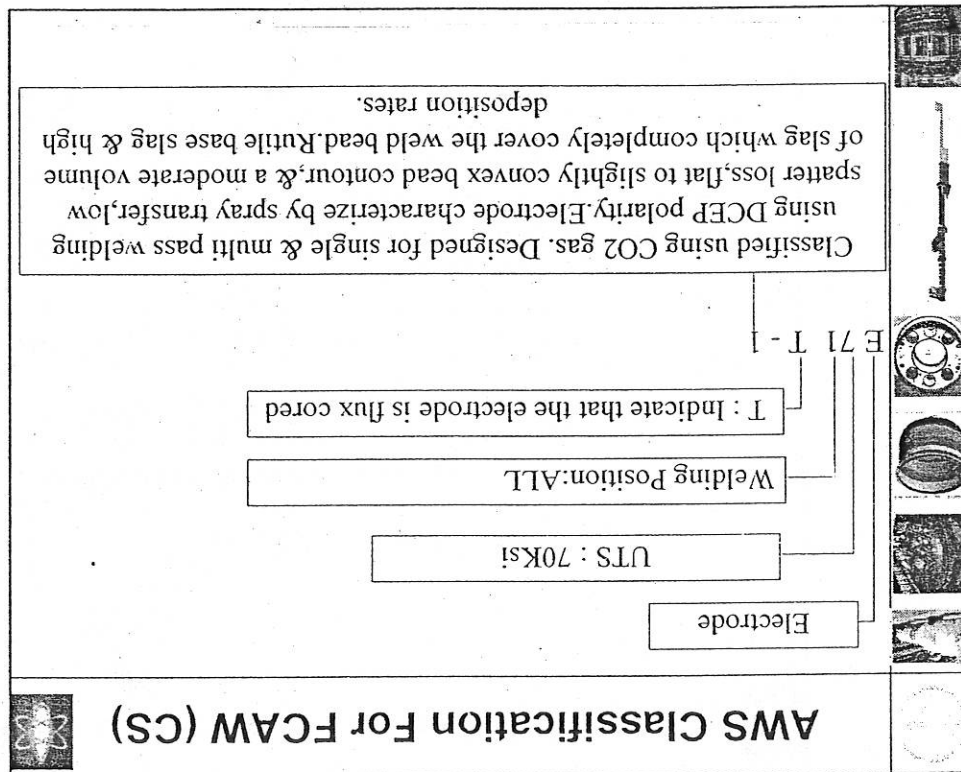


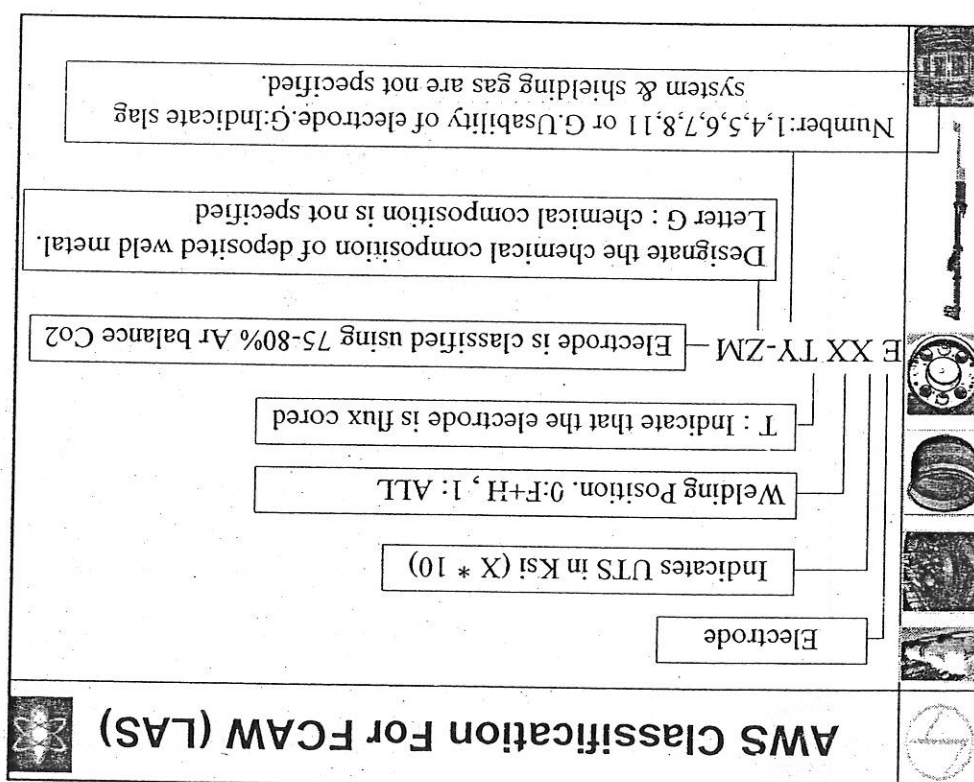
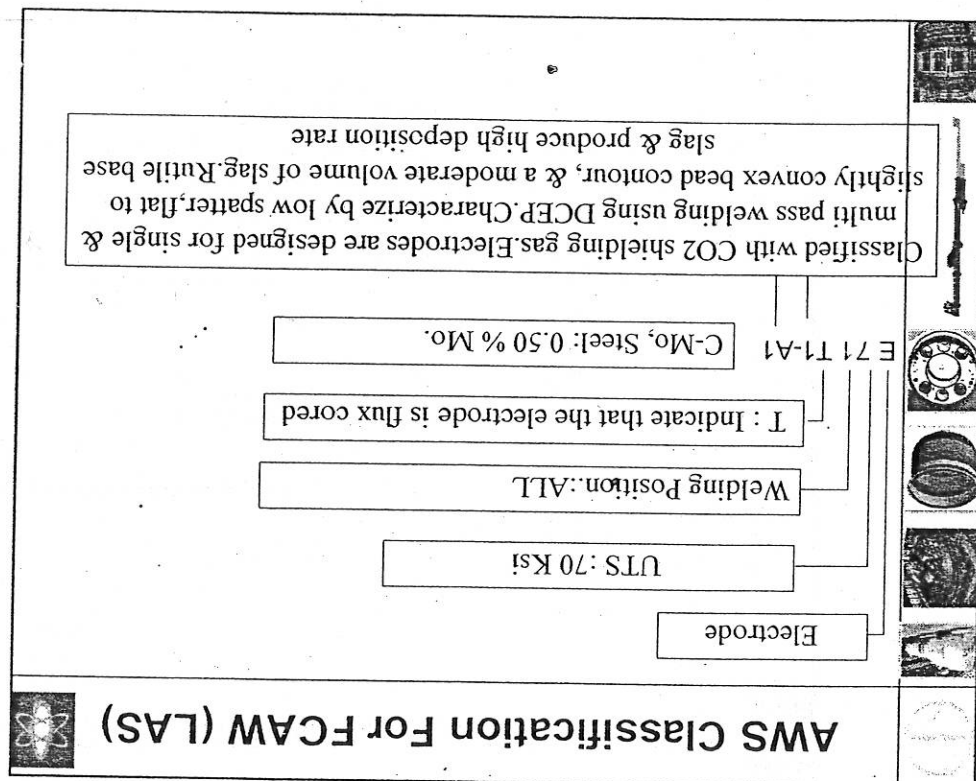


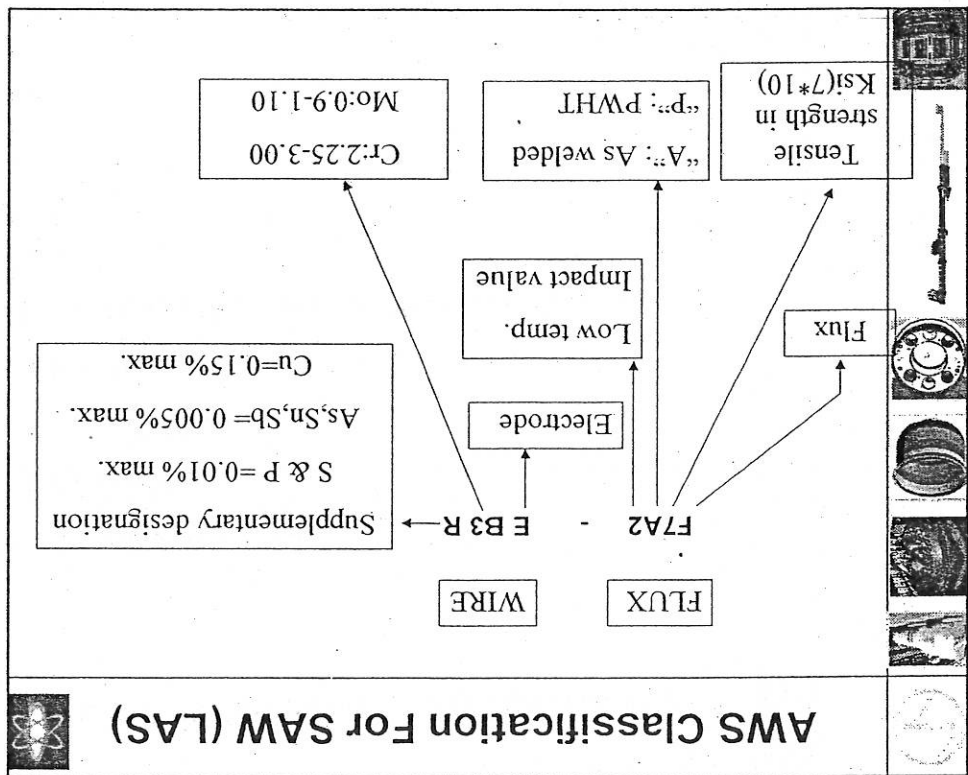
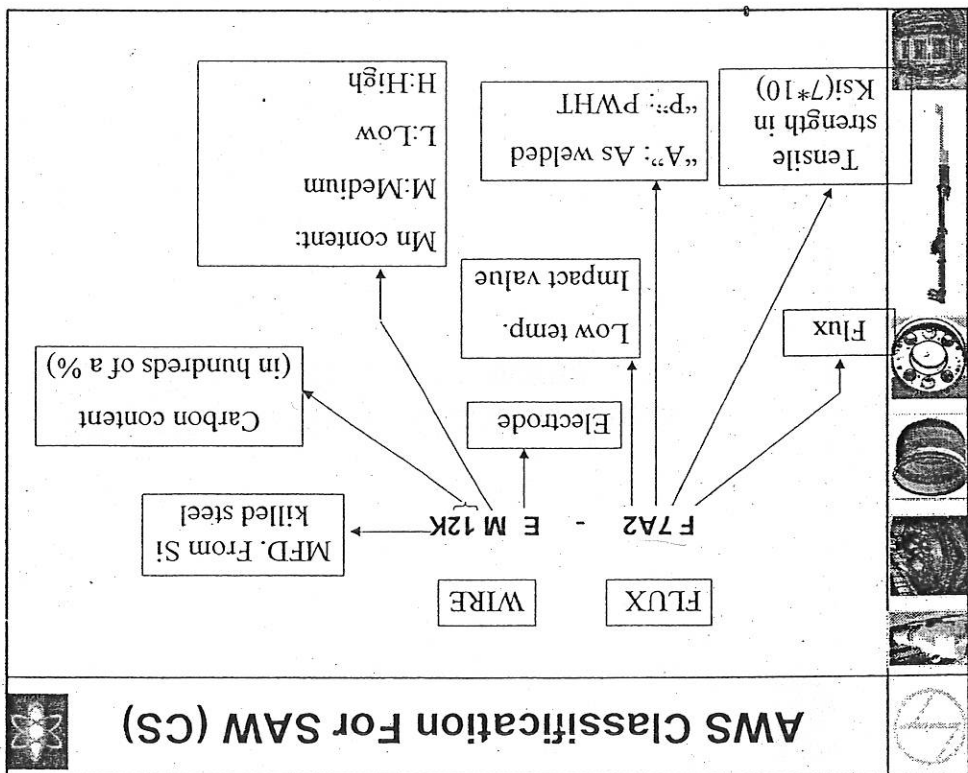
AWS Classification	Welding Current	Welding Position
EXXX(X)-15	DCEP	ALL
EXXX(X)-25	DCEP	H, F
EXXX(X)-16	DCEP or AC	ALL
EXXX(X)-17	DCEP or AC	ALL
EXXX(X)-26	DCEP or AC	H, F






























	<b>Section A-General Requirements</b>	       
	• Classification according to	
	(1) Type of Current	
	(2) Type of Covering	
	(3) Welding Position	
	(4) Mechanical Properties of the weld metal	






	<b>Specification for Carbon Steel Electrodes for SMAW</b>	       
---	---	---




AWS Classification	Type of Covering	Welding Position	Type of Current	E7014	Iron powder, Titania	F, V, OH, H	AC, DCEP or DCEN
E7015	Low Hydrogen Sodium	F, V, OH, H	DCEP	E7016	Low Hydrogen Potassium	F, V, OH, H	AC or DCEP
E7018	Low Hydrogen Potassium	F, V, OH, H	AC or DCEP	E7018M	Low Hydrogen Iron powder	F, V, OH, H	DCEP
E7028	Low Hydrogen Potassium	H-Fillet, F	AC or DCEP				









# Electrode Classification











	Electrode Classification							
	AWS Classification	Type of Covering	Welding Position	Type of Current	E6010	High Cellulose Sodium	F, V, OH, H	DCEP
	E6011	High Cellulose Potassium	F, V, OH, H	AC or DCEP	E6012	High Titania Sodium	F, V, OH, H	AC or DCEN
	E6013	High Titania Potassium	F, V, OH, H	AC, DCEP or DCEN	E6019	Iron oxide Titania Potassium	F, V, OH, H	AC, DCEP or DCEN
	E6020	High Iron Oxide	H-Fillet, F	AC or DCEN				

     	<p><b>Section B-Tests, Procedures &amp; Requirements</b></p> <p>• Summary of Tests</p> <p>Chemical Composition</p> <p>Mechanical Properties</p> <p>Soundness of Weld Metal</p> <p>Moisture Content of Low Hydrogen Electrode</p> <p>Usability of Electrode</p> <p>• Retests</p> <p>Twice Retest allowed</p> <p>Results of both retest-Meeting the Requirements</p> <p>Retest Specimen-Taken from original/new test assembly</p> <p>Chemical analysis-Retest for failed elements only</p>
---	--


## Tensile Test Requirements









AWS Classification	Tensile Strength(Ksi)	Yield Strength(Ksi)	Elongation(%)
E6010	60	48	22
E6011	60	48	22
E6012	60	48	17
E6013	60	48	17
E6019	60	48	22
E6020	60	48	22
E7014	70	58	17
E7015	70	58	22
E7016	70	58	22
E7018	70	58	22
E7024	70	58	17
E7028	70	58	22


# Weld Test Assemblies

- One or more of following Assemblies Required
- (1) Weld pad - Chemical analysis of undiluted weld metal
- (2) Groove weld-Mechanical properties & Soundness
- (3) Fillet Weld for usability of electrode
- (4) Groove weld-Transverse tensile & longitudinal bend-E6022
- (5) Groove weld-Mechanical properties & Soundness-E7018M



# Thank You






**WELDING & BRAZING QUALIFICATION  
ASME SEC. IX -**

**Training Material for Welding Technology  
Programme for M.E. Students of  
The Maharaja Sayajirao University of Baroda-  
Varodara, sponsored by L&T.**

**LARSEN & TOUBRO LIMITED  
Heavy Engineering Division  
HAZIRA**









A Presentation  
on  
ASME SECTION IX  
By: Hernal Desai  
Welding Engineering

1




ASME SECTION IX  
➤ Qualification standards for Welding & Brazing  
Procedures, Welders, Brazers, & Welding &  
Brazing Operators.

2



## Welding Qualifications

- Welding Procedure Qualification
- Welders' or Welding Operators' Performance Qualification



## ASME SECTION IX


Divides into Two Parts :

- Part QW- Welding
- Part QB- Brazing

**Part QW - Welding**


- Article I – Welding General Requirements
- Article II – Welding Procedure Qualification
- Article III – Welding Performance Qualification
- Article IV – Welding Data





## WPS & PQR

- WPS: A written qualified welding procedure prepared to provide direction for making production welds to code requirement
- Contents of WPS: Essential, Non Essential, and, when required Supplementary essential variables for each welding process used in WPS.
- Changes to the WPS: May be made in non essential variables to suit production requirements without re-qualification.
- Availability of the WPS: WPS used for code production welding shall be available for reference & review by AI at fabrication site.



## WPS & PQR

**Purpose :**

- To determine that the weldment proposed for construction is capable of having the required properties.

WPS : Welding Procedure Specification

PQR : Procedure Qualification Record




[illegible]

- Multiple WPSs with One PQR / Multiple PQRs With One WPS
- Several WPS may be prepared from the data on a single PQR
- Single WPS may cover several essential variable changes as long as a supporting PQR exist for each essential variable & when required, supplementary essential variable

WPS & POR


[illegible]



## Welding Procedure Qualification

- Proves the Quality / Properties of Weld Joint Prepared by a set of welding variables
  - Welding Process
  - Base Material
  - Welding consumable
  - Welding Parameters & Techniques ( Position, Polarity, Preheat, Inter Pass Temp.)
  - PWHT etc.
- Qualification limited to the essential variables of the Specific Process

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## Welding Procedure Qualification

- WELDING DATA
  - A set of Welding Variables involved in Preparing a Weld Joint.
- ESSENTIAL VARIABLE
  - A change in welding condition which will affect the mechanical properties (Other than notch toughness) of weld joint.
- SUPPLEMENTARY ESSENTIAL VARIABLE
  - A change in welding condition which will affect the notch toughness properties of weld joint
- NONESSENTIAL VARIABLE
  - A Change in welding condition which will not affect the mechanical properties of the weld joint

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## Welding Performance Qualifications

- Mandatory Requirement from Codes /Standards / Regulations
- Qualification Tests in accordance with the Applicable Code / Standards / Regulation.
- Acceptance Criteria of Test Results as per ASME SEC IX
- Qualification Records and Test Results to be Documented

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## Welder Qualification as per ASME SEC IX


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## Welding Performance Qualification

- Ascertain the skill of a welder or a welding operator to Produce defect free/sound weld
- Makes A Weld Coupon Using an Approved WPS of a Qualified Procedure.
- Weld Coupon Undergoes Soundness Test
- Each Qualified Welder Shall be Assigned by A Unique Welder Number
- Welders' Qualifications Records Are Documented
- Performance Qualification limited to the essential variables of the Specific Process

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## How To Qualify A Welder

- 1) Understand ASME Sec. IX - Welding Performance Qualifications
  - Variables For Different Processes – QW 350
  - Limits Of Positions Qualified & Dia – QW 461
  - Testing Requirements – QW 304-1

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## Welding Performance Qualification



Important Definitions as per ASME SEC IX

- Welder: One who performs manual or semiautomatic welding.
- Welding Operator: One who operates machine or automatic welding equipment.
- Manual Welding: Welding wherein the entire welding operation is performed & controlled by hand.

Contd.

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## Welding Performance Qualification



- Semiautomatic Welding: Arc welding with equipment which controls only the filler metal feed. The advance of welding is manually controlled.
- Machine Welding: Welding with equipment that has controls that are manually adjusted by the welding operator in response to visual observation of welding.
- Automatic Welding: Welding with equipment which performs the welding operation without adjustment of the controls by a welding operator.

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## Welding Performance Qualification



- Backing: A material placed at the root of a weld joint for the purpose of supporting molten weld metal
- Double welded joint: A joint that is welded from both sides.
- Single-welded joint: A joint welded from one side only.
- Consumable Insert: Filler metal that is placed at joint root before welding, & intended to completely fused into the root to become part of the weld.

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## Welding Performance Qualification



- F-NUMBER: Assign filler wire in order to reducing the welder procedure & performance qualifications. (QW-432)
- P-NUMBER: Assign to base metal in order to reducing the welder procedure qualifications. (QW-420)
- Retainer: Non consumable material, metallic or non metallic, which is used to contain or shape molten weld metal.

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## Welding Performance Qualification

- WELDING DATA
- A set of Welding Variables involved in Performing a Weld Joint
- ESSENTIAL VARIABLE
- A change in welding condition which will affect the ability of welder to deposit sound weld metal
- NONESSENTIAL VARIABLE
- A Change in welding condition which will not affect the ability of welder to deposit sound weld metal

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## Welding Performance Qualification

QW-416  
WELDING VARIABLES  
Welder Performance  
Essential

Paragraph	Brief in Variables	QW-352	SMAW QW-353	SAW QW-354	GMAW QW-355	GTAW QW-356	PAW QW-357
QW-402 Joints	4 - Backing	X	X		X	X	X
QW-403 ESCR	16 - Maximum qualified 17 - Pipe diameter	X	X	X	X	X	X
Material	18 - P-Number	X	X	X	X	X	X
	19 - Filler	X	X	X	X	X	X
QW-404 Filler	21 - F-Number	X	X	X	X	X	X
	22 - Inserts					X	X
	23 - Solid or metal cored or flux-cored					X	X
Finish	30 - Weld deposit	X	X	X	X	X	X
	31 - Weld deposit	X					
QW-405 Positions	32 - Limit (i.e. etc. etc.)						
	33 - Position	X	X	X	X	X	X
	34 - Type (i.e. etc. etc.)	X	X	X	X	X	X
QW-406 Gas	35 - Type (i.e. etc. etc.)						
	36 - Transfer mode	X					
QW-409 Electrical	37 - Current or polarity						

Welding Processes:  
GTAW  
SMAW  
SAW  
Shielded metal-arc welding  
Submerged-arc welding  
Gas metal-arc welding  
PAW  
Plasma-arc welding

Legend:  
+ Change  
- Addition  
1 Downhill  
2 Thickness

NOTE:  
(1) For description, see Section IV.  
(2) Flux-cored arc welding as shown in QW-355, with or without additional shielding from an externally supplied gas or gas mixture, is included.

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## Welding Performance Qualification



### Essential Variables – Automatic Welding

- Change from automatic to machine welding
- Change in the welding process
- EBW : Addition or deletion of filler metal
- EBW : Change from vacuum to out of vacuum equip. or vice versa.
- Laser welding : Change in laser type
- Friction Welding: Change from continuous drive to inertia or vice versa.

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## Welding Performance Qualification



### Essential Variables – Machine Welding

- Change in the welding process
- Change from direct visual control to remote visual control & vice-versa
- Deletion of AVC for GTAW
- Deletion of automatic joint tracking
- Deletion of consumable insert.
- Deletion of backing
- Change from single pass per side to multiple passes per side but not the reverse.


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Welding Performance Qualification		
Material Grouping(P-Numbers)		
Base Metal	Welding	Brazing
Steel and steel alloys	P-No. 1 through P-No. 11 incl. P-No. 5A, 5B, and 5C	P-No. 101 through P-No. 103
Aluminum and aluminum-base alloys	P-No. 21 through P-No. 25	P-No. 104 and P-No. 105
Copper and copper-base alloys	P-No. 31 through P-No. 35	P-No. 107 and P-No. 108
Nickel and nickel-base alloys	P-No. 41 through P-No. 47	P-No. 110 through P-No. 112
Titanium and titanium-base alloys	P-No. 51 through P-No. 53	P-No. 115
Zirconium and zirconium-base alloys	P-No. 61 through P-No. 62	P-No. 117

Welding Performance Qualification		
QW-423 Alternate Base Material for Welder Qualification		
Base Metal(s) for Welder Qualification	Qualified Production Base Metal(s)	
P-No. 1 through P-No. 11, P-No. 34, or P-No. 41 through P-No. 47	P-No. 1 through P-No. 11, P-No. 34, P-No. 41 through P-No. 47 and unassigned metals of similar chemical composition to these metals	
P-No. 21 through P-No. 25	P-No. 21 through P-No. 25	
P-No. 51 through P-No. 53 or P-No. 61 through P-No. 62	P-No. 51 through P-No. 53 and P-No. 61 through P-No. 62	





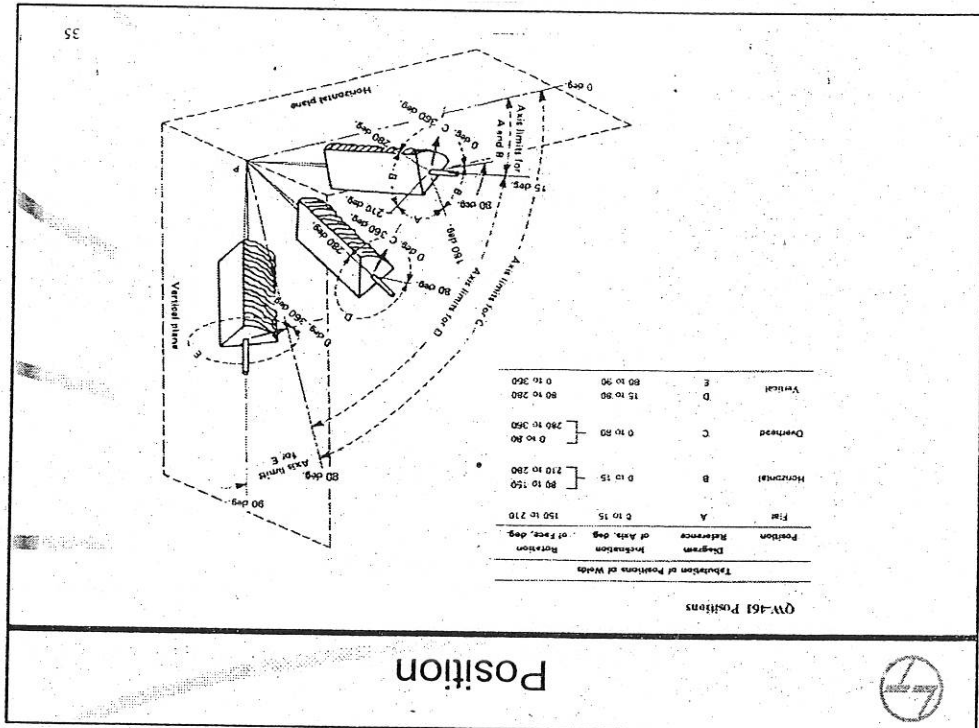
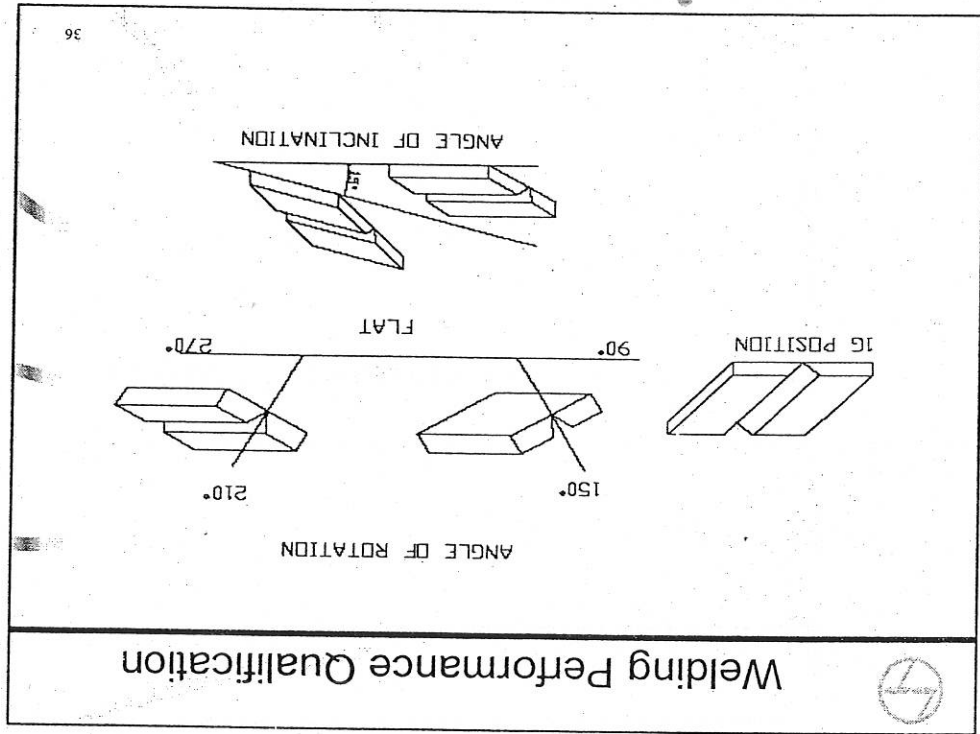
Welding Performance Qualification			
			
Important F-NUMBERS			
QW-432 F-NUMBERS Grouping of Electrodes and Welding Rods for Qualification			
F-No.	ASME Specification	AWS Classification	
4	SFA-5.1	EXX15	
4	SFA-5.1	EXX16	
4	SFA-5.1	EXX18	
4	SFA-5.1	EXX18M	
4	SFA-5.1	EXX48	
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-15	
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-16	
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-17	

Sensitization Band  $\rightarrow 1025$  to  $1050 \text{ cm}^{-1}$

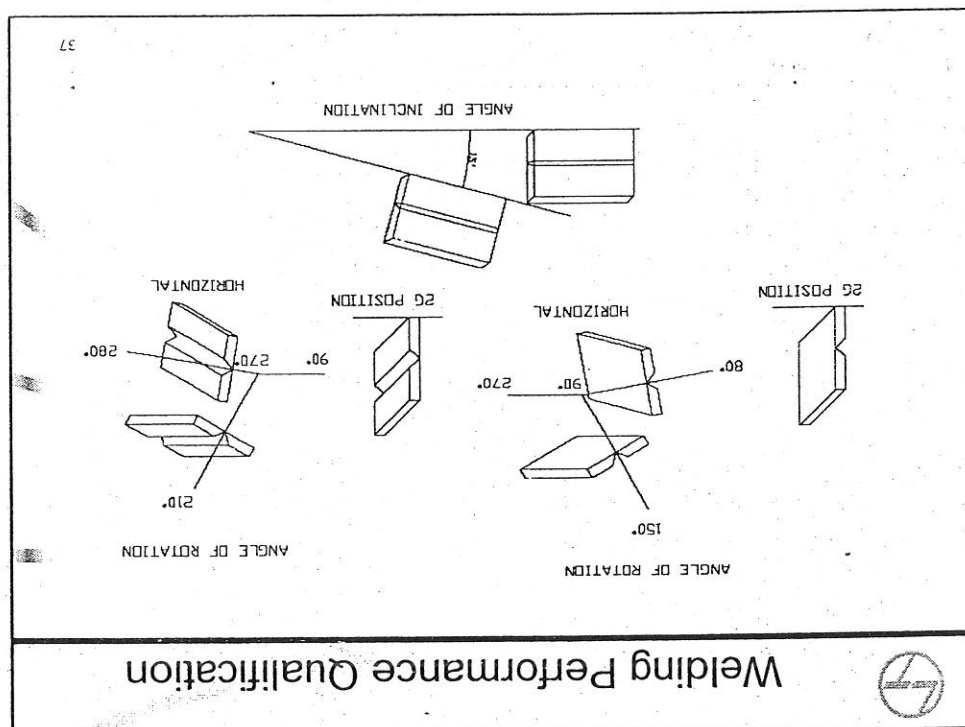
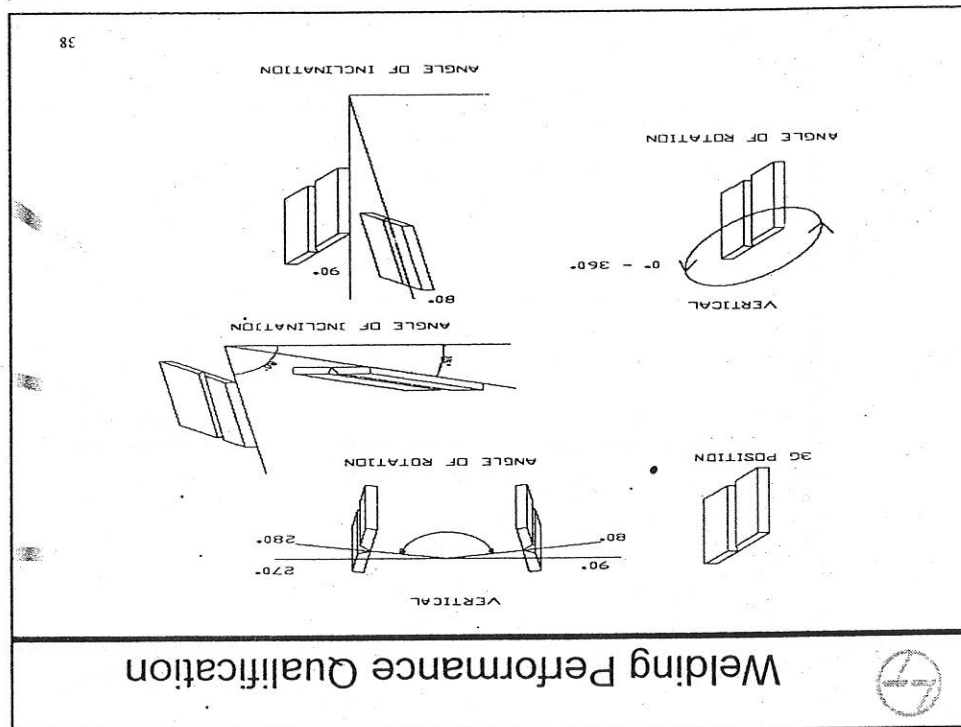
10/10/10

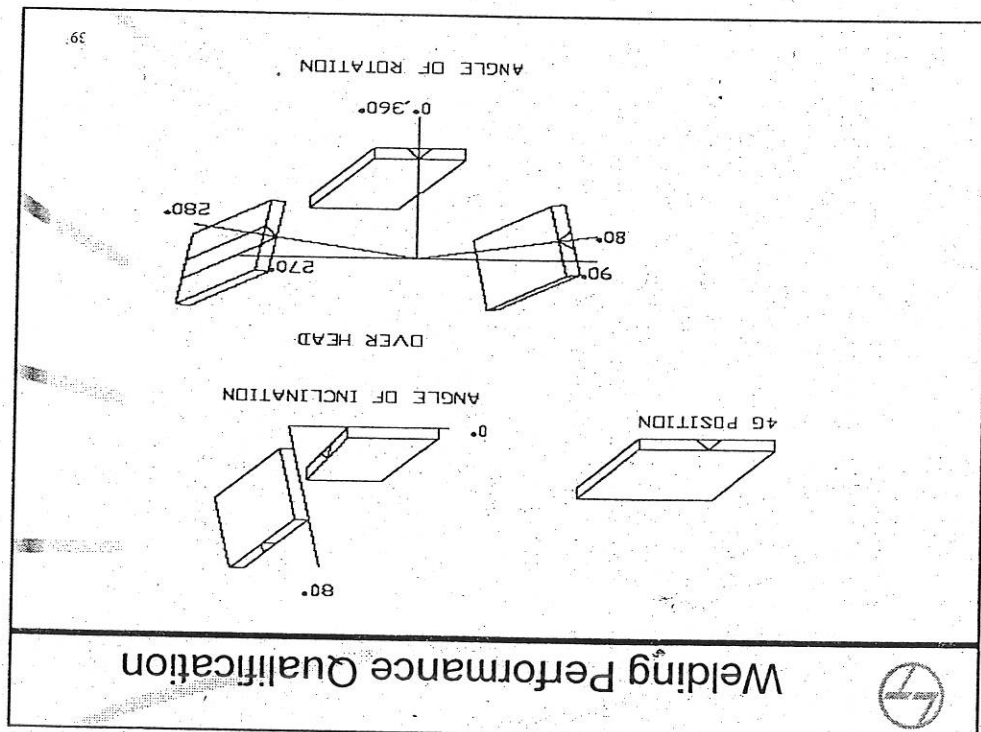
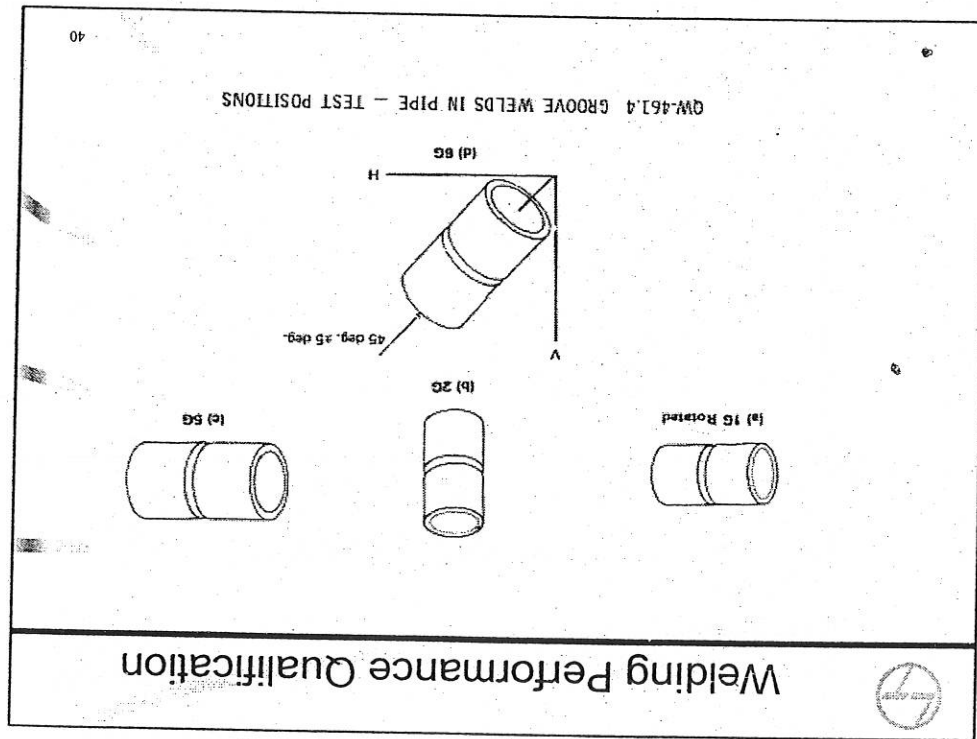
Groove Weld Positions – QW461					
Sr No.	Groove Position	Base Metal Position		Inclination of Axis in °	
		Plate	Pipe		
1	1G Flat	Horizontal	Pipe Axis Horizontal – in Rotation	0 - 15	
2	2G Horizontal	Vertical	Pipe Axis Vertical	0 - 15	
3	3G Vertical	Vertical	NA	80 – 90 15 - 80	
4	4G Over Head	Horizontal	NA	0 - 80	
5	5G	NA	Pipe Axis Fixed Horizontally	0 - 15	
6	6G	NA	Pipe Axis Fixed 45° inclined	+ or - 5	

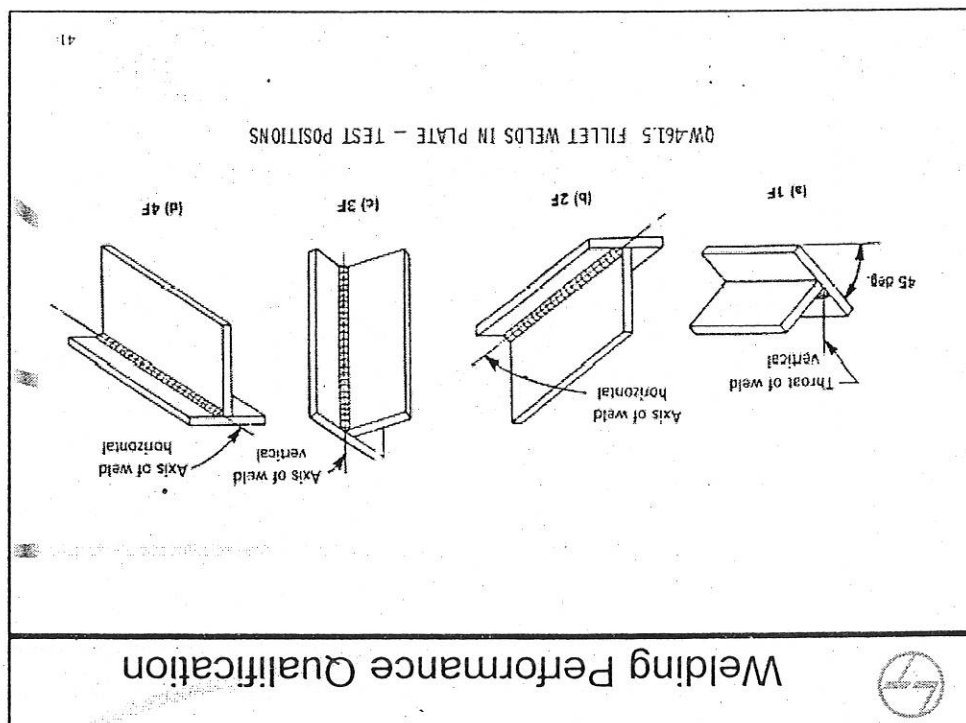
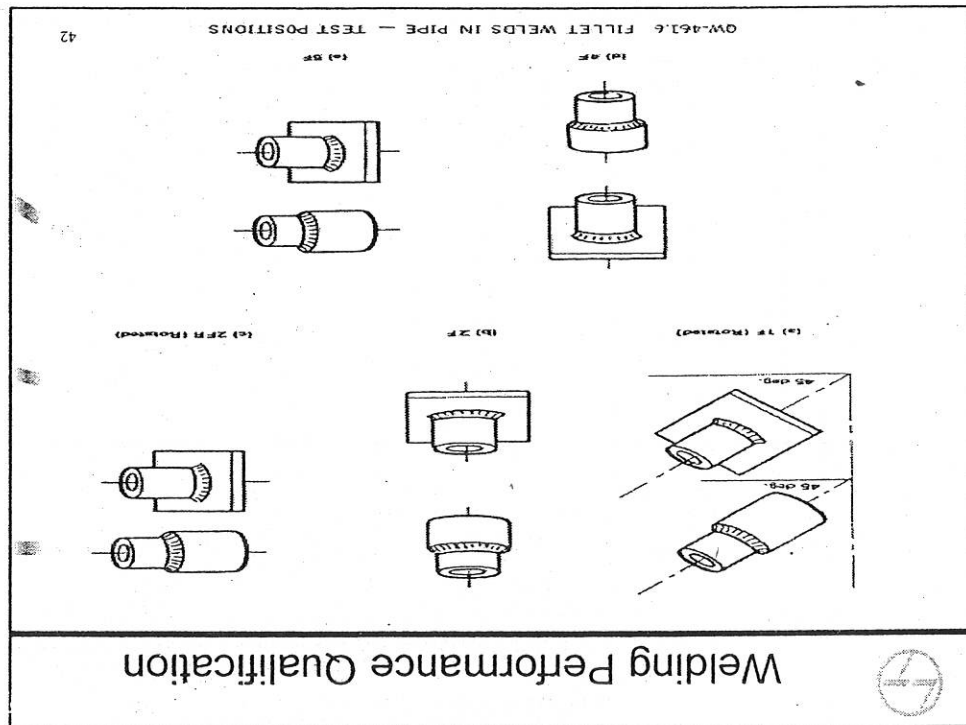
Position For Qualification	








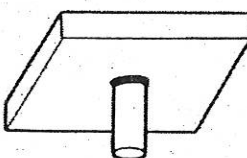




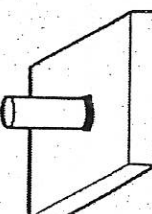


## Welding Performance Qualification

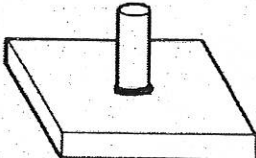
QW-461.7 STUD WELDS - TEST POSITIONS



(a) 1S



(b) 2S



(c) 4S

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Qualification Test		Position & Type of Weld Qualified			
Weld	Position	Plate & Pipe Over 24"	Pipe ≤ 24"	Fillet Plate & Pipe	
Plate	1G	F	F*	F	F
	2G	F, H	F* & H*	F, H	
Groove	3G	F, V	F*	F, H, V	F, H, V
	4G	F, O	F* & H*	F, H, O	
Pipe	2G, 3G & 4G	ALL	F* & H*	ALL	SP & F
	Spcl. Position	SP & F	SP & F	SP & F	
Pipe	1G	F	F	F	F
	2G	F, H	F* & H*	F, H	
Groove	5G	F, V, O	F, V, O	F, H, V, O	F, H, V, O
	6G	ALL	ALL	ALL	
Pipe	2G & 5G	ALL	ALL	ALL	SP & F
	Spcl. Position	SP, F	SP, F	SP, F	

\* Pipe 2 1/2" OD and Over, \$ Pipe OD Restrictions As Per QW 452.3, 452.4 & 452.6

Performance Qualification		
Thickness Limits – QW 452.1(b)		
Thickness "t" of Weld Metal in the Coupon in mm (in)	All	13 (1/2) and Over With Minimum Three Layers
Thickness of Weld metal Qualified	2t	Maximum To Be Welded

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Performance Qualification		
Groove-Weld, Pipe Dia. Limits QW 452.3		
Out Side Dia. Of Test Coupon in mm (in)	Min.	Max.
	Size Welded	Unlimited
Less Than 25 (1")	25 (1")	Unlimited
25 (1") to 73 (2 7/8")	73 (2 7/8")	Unlimited
Over 73 (2 7/8")		Unlimited

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Notes:-  
 1) Type & Number of Tests as per QW-452.1  
 2) Welders Qualified on Groove, Are Also Qualified for making Fillets of all Sizes on Any Thickness & Any Pipe Dia.

## Performance Qualification

Thickness limits & test specimen for Overlay

QW-453  
PROCEDURE/PERFORMANCE QUALIFICATION THICKNESS LIMITS AND TEST SPECIMENS FOR HARD-FACING (WEAR-RESISTANT) AND CORROSION-RESISTANT OVERLAYS

Thickness of Test Coupon (T)	Corrosion-Resistant [Note (1)]		Hard-Facing Overlay (Wear-Resistant) [Note (2)]	
	Normal Base Metal Thickness Qualified (T)	Type and Number of Tests Required	Normal Base Metal Thickness Qualified (T)	Type and Number of Tests Required
Procedure Qualification Testing	Less than 1 in. (25 mm) T	T qualified to unlimited	1 in. (25 mm) to unlimited	Notes (3), (7), (8), and (9)
Performance Qualification Testing	Less than 1 in. (25 mm) and over T	T qualified to unlimited	1 in. (25 mm) and over T	Notes (4), (5), and (9)
	1 in. (25 mm) T	T qualified to unlimited	1 in. (25 mm) T	T qualified to unlimited
	1 in. (25 mm) and over T	T qualified to unlimited	1 in. (25 mm) and over T	Notes (6) and (10)

## How To Qualify A Welder

- 2) Train The Welder For The Process To Be Qualified
- Welder Shall Posses Adequate Skill In Performing the Process.
  - He Shall have Necessary Knowledge In Operation Of Machine, Precautions In Storage & Usage Of Consumable, Defects In Welding, Their Causes And Remedy.
  - He Shall Practice Welding In The Particular Position In Which He Is To Be Tested / Qualified

## How To Qualify A Welder



### 3) Preparation Of Test Coupon (Grove)

- Prepare A Test Coupon Out of 300 x 150 x 20 mm Plates Or Pipe Of 150mm long As Per Applicable WPS.
- WEP ( Angle, Root Face & Root Opening ) Shall Be As Per The WPS
- Provide Run in & Run Out Coupons on plate & Fix the Test Coupon In In Any One Of The Positions To Be Qualified.
- Weld The Groove Fully In The Position
- All Welding Variables Shall be Strictly Within The Qualified WPS

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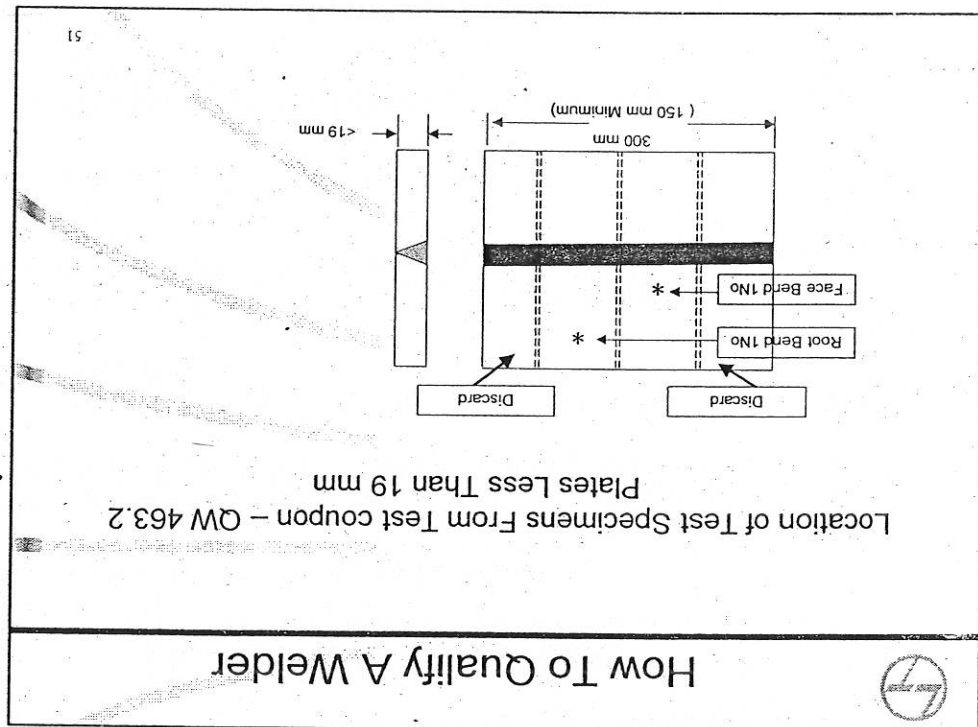
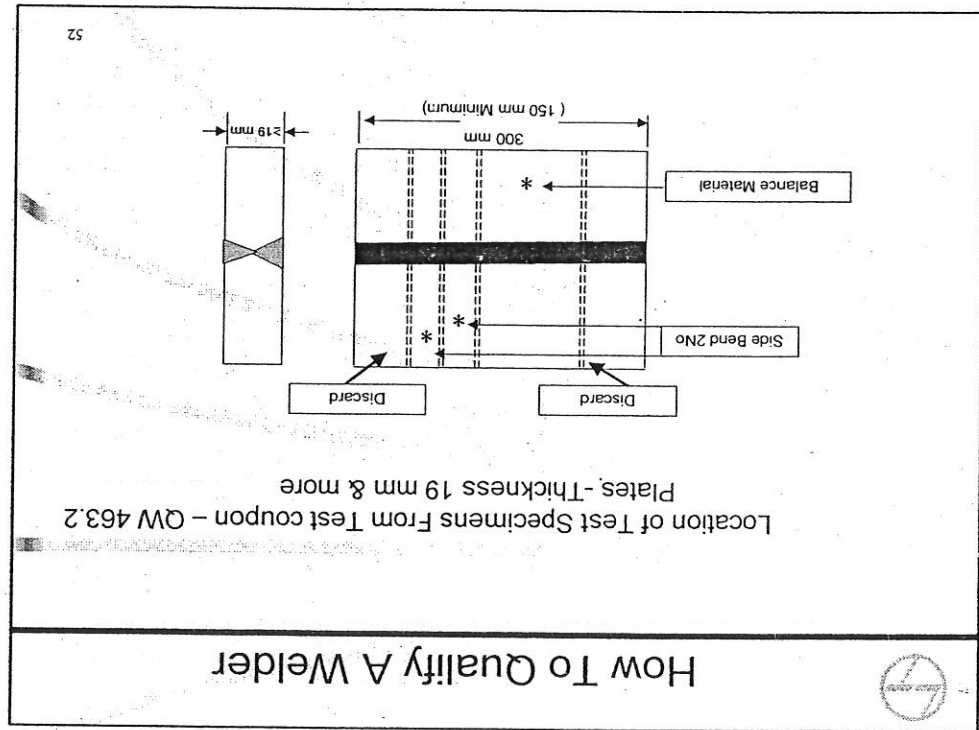
## How To Qualify A Welder



### 4) Type Of Test Required On Welded Coupon (Grove) (QW-302)

- Visual Examination – QW 302.4  
Completed Coupon Shall be Subjected To Visual Inspection
- Mechanical Test - QW 452.1  
For t < 10 mm , Root Bend :- 1 No, Face Bend :- 1  
For t = 10 to < 19 mm , Side Bend :- 2 No or 1 RB & 1 FB  
For t ≥ 19 mm , Side Bend :- 2 No  
(For 5G / 6G – 2 Face & 2 Root Or 4 Side Bends)
- Alternate to Mechanical Tests, Radiograph the Coupon – 6 " Minimum Length

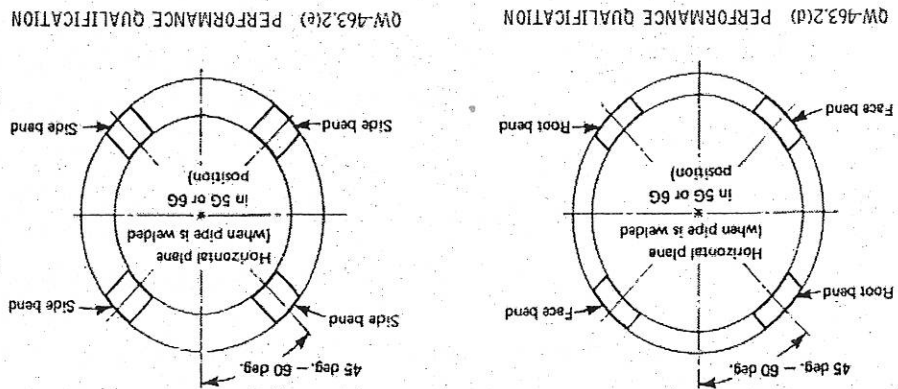
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## How To Qualify A Welder

### Qualification in 5G or 6G

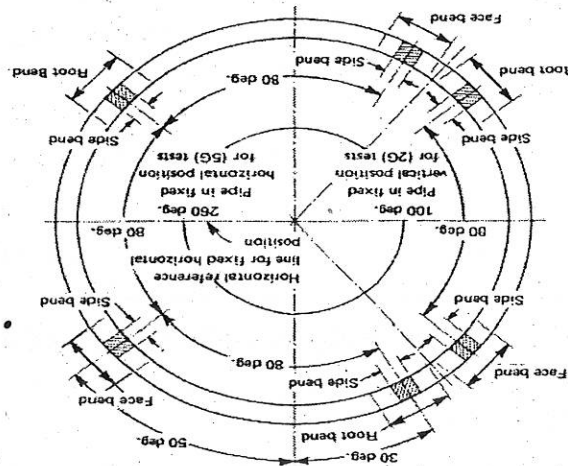


Four side bend Or two root bend & 2 face bend specimen are required.

QW-463.2(e) PERFORMANCE QUALIFICATION

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## How To Qualify A Welder



QW-463.2(f) PIPE - 10 in. (254 mm) ASSEMBLY PERFORMANCE QUALIFICATION

Assembly performance qualification (2G+5G) : Six bend specimen

54



## How To Qualify A Welder

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• QW 191.2 Radiography Acceptance Criteria

QW-191.2.1 Terminology


Linear Indication:  $L > 3W$

-Crack, LF, Slag

Rounded Indication:  $L \leq 3W$

-Porosity & inclusions such as slag or tungsten

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## How To Qualify A Welder

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5) Acceptability Criteria For Tests

- Visual Examination – QW 302.4
- Free From Incomplete Fusion / Penetration and Surface Defect
- Bend Test - QW 163
- Opening not more than 3 mm in any direction on Convex Surface Within the Weld & HAZ
- R T – QW 191.2
- No Crack, LF & Incomplete Penetration
- No Slag, Cluster Of Porosity & Other Inclusions Beyond Specified Limit

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(Jop) lack of penetration possible only in GTAW not SMAW  
 b/c - is small & side by chip back welding can done

## How To Qualify A Welder



### QW-191.2.2 Acceptance standards

#### (a) Following Linear Indications are unacceptable

- Crack or LF
- Elongated inclusion which has a length greater than
  - 1). 3 mm for t up to 10 mm
  - 2).  $1/3 \times t$  for t over 10 to 57 mm
  - 3). 19 mm for t over 57 mm
- Group of slag inclusions in line with aggregate length
  - > t in a length of 12t except when distance between the successive imperfections exceeds 6L where L is length of longest imperfection

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## How To Qualify A Welder



#### (b) Rounded Indication

- 1). Permissible dimensions for rounded indication shall be 20% of t or 3 mm whichever is smaller
  - 2). For welds in  $T < 3$  mm, max. 12 no of indication in 150 mm are acceptable
  - 3). For welds in  $T \geq 3$  mm, refer charts in Appendix I
- Rounded indications less than 0.8 mm in diameter shall not be considered in the radiography acceptance test of welders & welding operators when  $T \geq 3$  mm

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## How To Qualify A Welder for Fillet Weld

QW-452.5


FILLET-WELD TEST

Type and Number of Tests Required [QW-462.4(b) or QW-462.4(c)]	Thickness of Test Coupon as Welded, in. (mm)	Range Qualified	Type of Joint
Macro	1	All base material thicknesses, fillet sizes, and diameters $2\frac{1}{8}$ (73) O.D. and over [Note (1)]	Tee fillet
Fracture	1	Less than $\frac{3}{16}$ (4.8) $\frac{3}{16}$ - $\frac{7}{8}$ (9.8-10)	

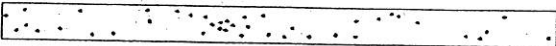
Fillet sizes, and diameters  $2\frac{1}{8}$  (73) O.D.  
 and over [Note (1)]  
 T to 2 T base material thickness, T  
 maximum fillet size, and all  
 diameters  $2\frac{1}{8}$  (73) O.D. and over  
 [Note (1)]

GENERAL NOTE: Production assembly mockups may be substituted in accordance with QW-181.2.1. When production assembly mockups are  
 used, range qualified shall be limited to the fillet sizes, base metal thicknesses, and configuration of the mockup.  
 NOTE:  
 (1)  $2\frac{1}{8}$  in. (73 mm) O.D. is considered the equivalent of NPS  $2\frac{1}{2}$ . For smaller diameter qualifications, refer to QW-452.4 or QW-452.6.

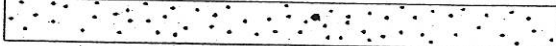
60




## APPENDIX I Rounded Indication Charts



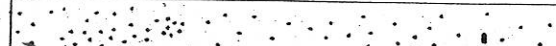
Typical Quantity and Size Permitted  
in 6 in. (152 mm) Length of Weld  
 $\frac{1}{8}$  in. (3.2 mm) to  $\frac{1}{4}$  in. (6 mm)  
Thickness



Typical Quantity and Size Permitted  
in 6 in. (152 mm) Length of Weld  
Over  $\frac{1}{4}$  in. (6 mm) to  $\frac{1}{2}$  in. (12 mm)  
Thickness



Typical Quantity and Size Permitted  
in 6 in. (152 mm) Length of Weld  
Over  $\frac{1}{2}$  in. (12 mm) to 1 in. (25 mm)  
Thickness



Typical Quantity and Size Permitted  
in 6 in. (152 mm) Length of Weld  
Over 1 in. (25 mm) Thickness

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# How To Qualify A Welder for Fillet Weld



## QW-452.4 SMALL DIAMETER FILLET-WELD TEST

Thickness Qualified	Minimum Outside Diameter (qualified, in. (mm))
All	Size welded

Outside Diameter of Test Coupon, in. (mm)	Thickness of Test Coupon as Welded, in. (mm)	Type of Joint
Less than 1 (25)	1 (25) to less than 2 7/8 (73)	Any groove
All	2 7/8 (73) and over	Any groove

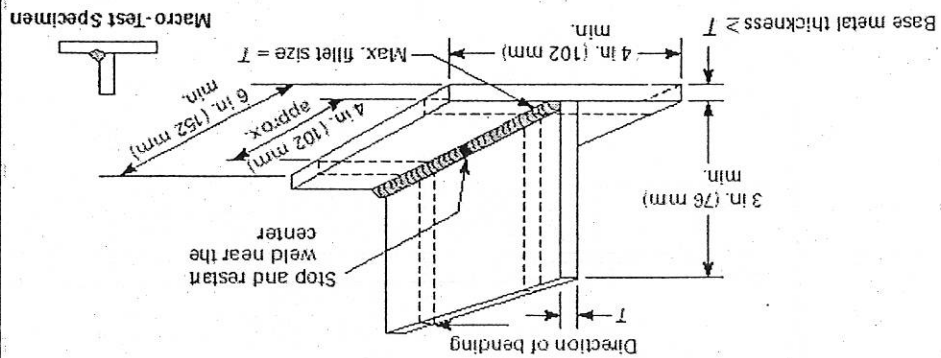
GENERAL NOTES:  
(a) Type and number of tests required shall be in accordance with QW-452.5.  
(b) 2 7/8 in. (73 mm) O.D. is considered the equivalent of NPS 2 1/2.

## QW-452.6 FILLET QUALIFICATION BY GROOVE-WELD TESTS

Type and Number of Tests Required	Thickness of Test Coupon as Welded, in. (mm)	Range Qualified	All thicknesses	Fillet sizes, and diameters	Fillet welds are qualified when a welder/welding operator qualifies on a groove weld test
1 (25) to less than 2 7/8 (73)	2 7/8 (73) and over	Any groove	Any groove	Any groove	Any groove

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# How To Qualify A Welder for Fillet Weld



## QW-462.4(b) FILLET WELDS — PERFORMANCE

GENERAL NOTE: Refer to QW-452.5 for  $T$  thickness/qualification ranges.

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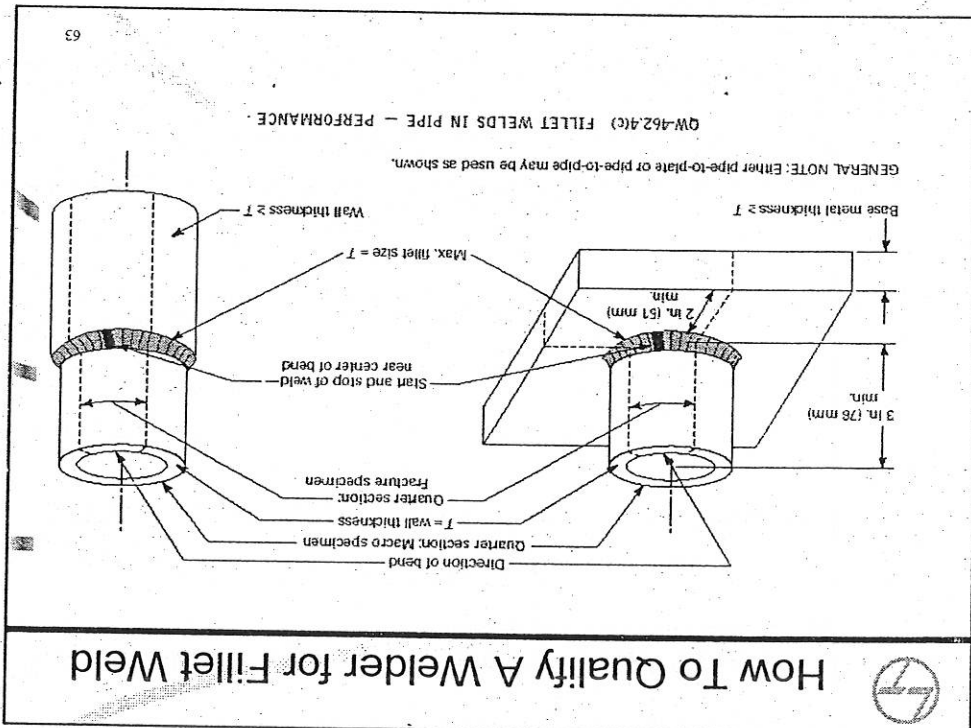
## How To Qualify A Welder for Overlay

Thickens of Test Coupon (7)		Crosion-Resistant Overlay [Note (1)]		Hard-facing Overlay (Wear-Resistant) [Note (2)]	
Thickens of Test Coupon (7)	Procedure Qualification Testing	Less than 1 in. (25 mm) $f$ and over 1 in. (25 mm) $f$ qualified to unlimited	Notes (4), (5), and (9)	$f$ qualified up to 1 in. (25 mm) to unlimited	Notes (3), (7), (8), and (9)
Performance Qualification Testing	Less than 1 in. (25 mm) $f$ and over 1 in. (25 mm) $f$ qualified to unlimited	Notes (6)	$f$ qualified to unlimited	Notes (6)	Notes (6) and (10)

QW-453  
PROCEDURE/PERFORMANCE QUALIFICATION THICKNESS LIMITS AND TEST SPECIMENS FOR HARD-FACING (WEAR-RESISTANT) AND CORROSION-RESISTANT OVERLAYS

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## How To Qualify A Welder for Fillet Weld





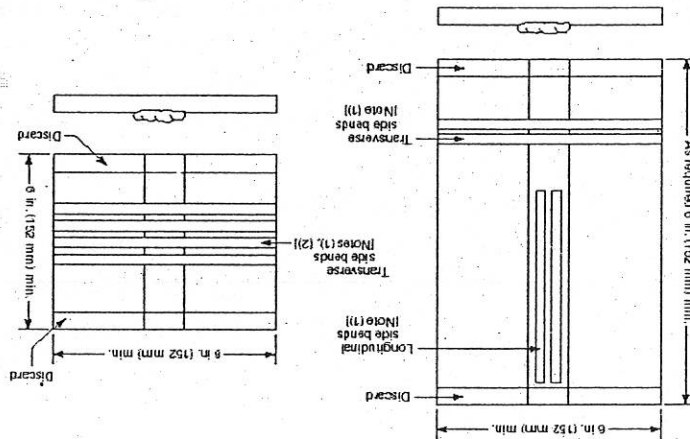
## How To Qualify A Welder for Overlay



- Size of Coupon: 150 X 150 X T
- WPQ on pipe: Length: 150 mm MIN. & a min. diameter to allow the required number of test specimen. Overlay shall be continuous around the circumference of the test coupon.
- Minimum width of overlay: 38 mm
- WPQ: for process where width of bead is > 13 mm, minimum three bead are required in first layer
- SB specimens are perpendicular to the direction of welding in accordance with QW161 Locations specified in QW-462.5(b) or QW-462.5(d)

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## How To Qualify A Welder for Overlay

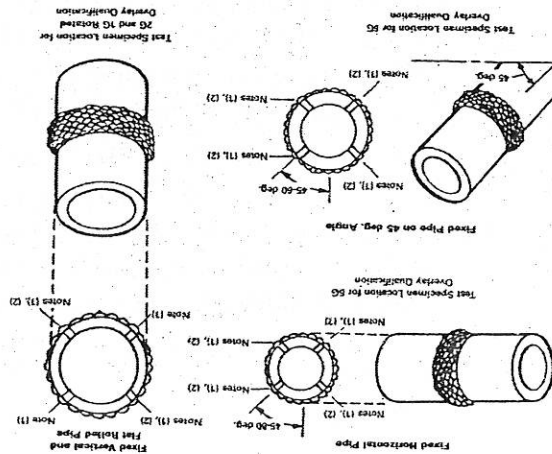


NOTES:  
 (1) Location for required test specimen removal — Procedure (QW-453). Four-side-bend test specimens are required for each position.  
 (2) Location for required test specimen removal — Performance (QW-453). Two-side-bend test specimens are required for each position.

QW-462.5(d) PLATE BEND SPECIMENS — CORROSION-RESISTANT WELD METAL OVERLAY

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## How To Qualify A Welder for Overlay



QW-462.5(c) PIPE BEND SPECIMEN — CORROSION-RESISTANT WELD METAL OVERLAY

(1) Location for required test specimen removal — Procedure QW-463

(2) Location for required test specimen removal — Procedure QW-463

NOTES:

GENERAL NOTE: Overlay may be on the inside or outside of pipe.

Test Specimen Location for TG and TS Located

Overlay Qualification

## QW-322 Expiration & Renewal Of Qualification

- QW-322.1 Expiration of Qualification
  - When welder Or welding operator has not welded with a process during a period of 6 months or more, his qualification for that process shall expires
  - When there is a specific reason to question welder or welding operator's ability to make welds that meet the specification, the qualification that support the welding he is doing shall be revoked.



*Thank You*

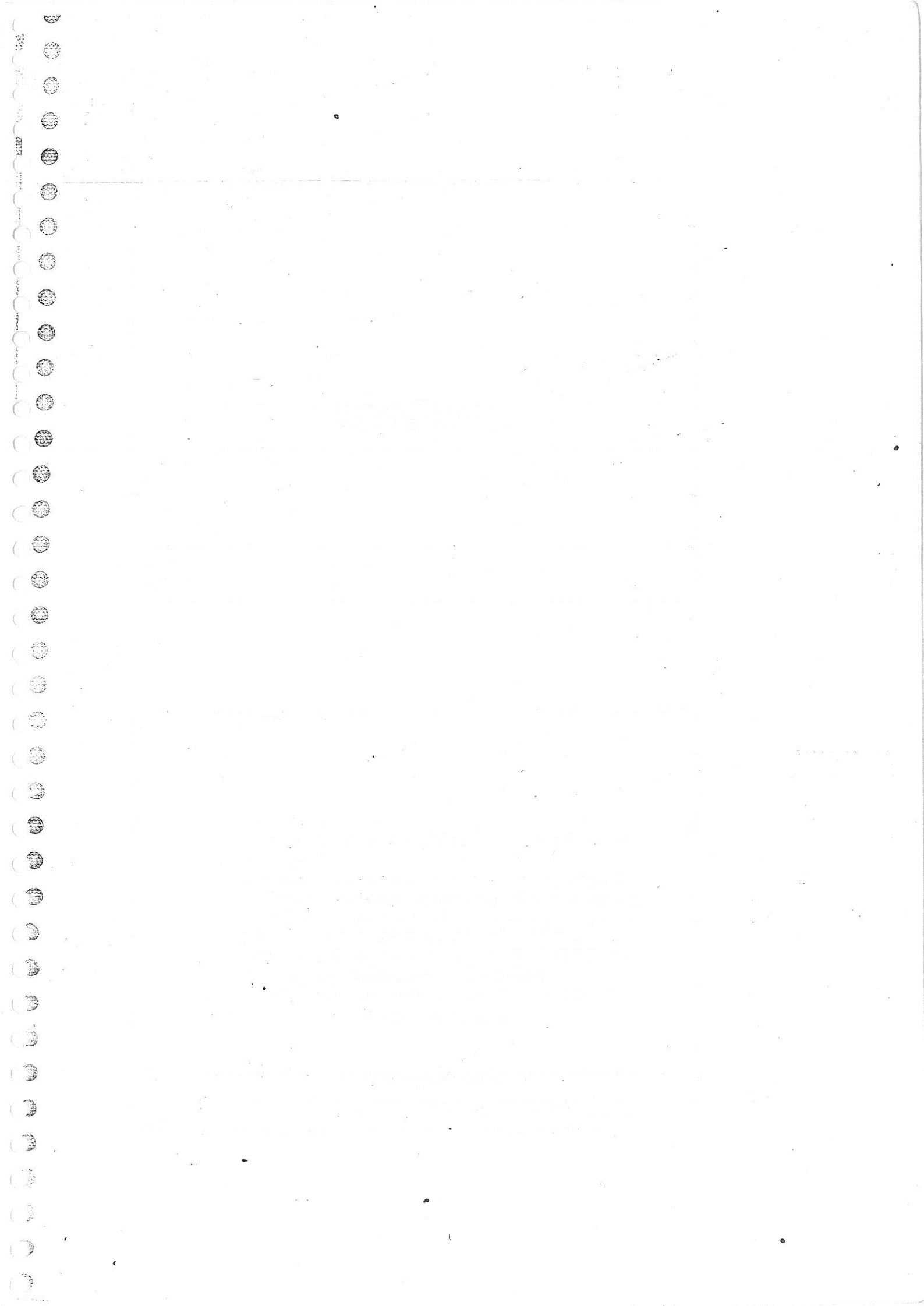
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- QW-322.1 Expiration of Qualification
  - Re-qualification for welders or welding operators whose qualifications have been revoked.
  - Renewal of qualification expired under expired under QW-322.1(a) may be made for any process by welding a single test coupon of either plate or pipe, of any material, thickness or diameter, in any position & by testing of that coupon as required by QW-301 & QW-302
  - Renewal of qualification may be done on production work (QW-322.1 (a) )

QW-322 Expiration & Renewal Of

Qualification






**ASME SECTION IX**

➤ Qualification standards for Welding & Brazing  
Procedures, Welders, Brazers, & Welding & Brazing  
Operators.


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**ASME SECTION IX – WPS / PQR**

A Presentation  
on


By: Hernal Desai  
Welding Engineering

1



## Welding Qualifications

- Welding Procedure Qualification
- Welders' or Welding Operators' Performance Qualification



## ASME SECTION IX

Divides into Two Parts :

- Part QW-Welding
- Part QB-Brazing

### Part QW - Welding


- Article I – Welding General Requirements
- Article II – Welding Procedure Qualification
- Article III – Welding Performance Qualification
- Article IV – Welding Data

WPS & PQR

**Purpose :**

- To determine that the weldment proposed for construction is capable of having the required properties.


WPS : Welding Procedure Specification  
PQR : Procedure Qualification Record



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WPS

- WPS: A written qualified welding procedure prepared to provide direction for making production welds to code requirement
- Contents of WPS: Essential, Non Essential, and, when required Supplementary essential variables for each welding process used in WPS.
- Changes to the WPS: May be made in non essential variables to suit production requirements without re-qualification.
- Availability of the WPS: WPS used for code production welding shall be available for reference & review by AI at fabrication site.



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Non essential  
Cover design

Welding Procedure Qualification	
Welding Data	• A set of Welding Variables involved in Preparing a Weld Joint.
Essential Variable	• A change in welding condition which will affect the mechanical properties (Other than notch toughness) of weld joint.
Supplementary Essential Variable	• A change in welding condition which will affect the notch toughness properties of weld joint <i>not mechanically properties</i>
Nonessential Variable	• A change in welding condition which will not affect the mechanical properties of the weld joint

Notch toughness is affected by heat input

$B_2 - 1.25 \text{ in } 0.5 \text{ m (Used as } P_4)$   
 $B_3 - 2.25 \text{ in } 1.0 \text{ m}$   
 $A_1 - 0.5 \text{ m } C$   
 $B_2 - \text{Flux wire / Rod (Input passing)}$

Welding Procedure Qualification	
Welding Data	• A set of Welding Variables involved in Preparing a Weld Joint.
Essential Variable	• A change in welding condition which will affect the mechanical properties (Other than notch toughness) of weld joint.
Supplementary Essential Variable	• A change in welding condition which will affect the notch toughness properties of weld joint <i>not mechanically properties</i>
Nonessential Variable	• A change in welding condition which will not affect the mechanical properties of the weld joint



PQR

- PQR: A record of the welding data used to weld a test coupon. Also contain test result of the tested specimen.
- Content of the PQR: PQR shall document all essential & when required, supplementary essential variables for each process used during welding of test coupon.
- Changes to PQR: Changes to PQR are permitted except
  - Editorial Correction
  - Addenda to the PQR
  - Additional information can be incorporated in PQR at a later date provided the information is sustained as having been the part of the original qualification condition by lab record or similar data.
- Availability of PQR: PQR shall be available upon request for review by AI. PQR need not be available to the welder or welding operator.


→ PIR must keep in office not give the shape

GENERAL INFORMATION									
NAME		ADDRESS		CITY		STATE		ZIP	
DATE		TIME		DAY		MONTH		YEAR	
TELEPHONE									
FACSIMILE									
TELETYPE									
TELEGRAPH									
TELEVISION									
RADIO									
OTHER									
REMARKS									
SIGNATURE									
PRINTED NAME									
TITLE									
ORGANIZATION									
BUSINESS ADDRESS									
TELEPHONE									
FACSIMILE									
TELETYPE									
TELEGRAPH									
RADIO									
OTHER									
REMARKS									
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TITLE									
ORGANIZATION									

to measure ~~welding~~ travel speed in mm/s  
Burning time (excluding stub length) weld bead length  
A time we have to measure








## WPS & PQR

- Multiple WPSs with One PQR / Multiple PQRs With One WPS.
- Several WPS may be prepared from the data on a single PQR
- Single WPS may cover several essential variable changes as long as a supporting PQR exist for each essential variable & when required, supplementary essential variable

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## Welding Procedure Qualification

- Proves the Quality / Properties of Weld Joint Prepared by a set of welding variables
- Welding Process
- Base Material
- Welding consumable
- Welding Parameters & Techniques ( Position, Polarity, Preheat, Inter Pass Temp.)
- PWHT etc.
- Qualification limited to the essential variables of the Specific Process

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How To Qualify Groove Butt Weld Procedure?

- Types of Tests & Acceptance Limits – Tension, Guided Bend, Notch Toughness – QW-141, 451, 153, 163, 171, 172, 462, 463
- Test Requirements – QW-451
- Test Specimen – Location, Dimension & Testing Procedure – QW-462, 463, 464, 466
- Qualifications – Range in Thickness – QW-451
- Record & Documentation of WPS, PQR

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How To Qualify Groove Butt Weld Procedure?

1) Understand ASME Sec. IX Classifications & Requirements

- Welding Data - Essential, Non Essential & Supplementary Essential Variables. – QW-251, 400
- Parent Metal Grouping - "P" No / S No; Group No – QW-420 & 422
- Filler Metal Grouping – "F" No – QW-431, 432, 433
- Weld Metal Composition Grouping – "A" No – QW-440, 441, 442
- Welding Positions, Groove & Fillet – QW-461

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A No - Undiluted weld metal composition

6-pass ~ On pass weld bead thickness

Paragraph	Symbol	Essential	Supplementary	Nonessential
QW-402 Joints	1. Groove design			X
	2. Backing			X
	3. Root spacing			X
	4. Reinforcement			X
QW-403 Base Metals	5. Group number		X	
	6. Tensile strength		X	
	7. Yield strength		X	
	8. Elongation		X	
	9. Hardness		X	
	10. P-No. qualified		X	
	11. P-No. 5/9/10		X	
QW-404 Filler Metals	12. Diameter		X	
	13. A-Number		X	
	14. F-Number		X	
	15. P-No. 5/9/10		X	
	16. P-No. qualified		X	
	17. Tensile strength		X	
	18. Yield strength		X	
	19. Elongation		X	
	20. Hardness		X	
QW-405 Positions	21. T-J vertical welding		X	
	22. Position		X	
	23. Position		X	
	24. AWS class		X	
	25. AWS class		X	
	26. AWS class		X	
	27. Diameter		X	
	28. A-Number		X	
	29. F-Number		X	
	30. P-No. 5/9/10		X	
	31. P-No. qualified		X	
	32. Tensile strength		X	
	33. Yield strength		X	
	34. Elongation		X	
	35. Hardness		X	
QW-406 Physical	36. Decrease > 100°F (56°C)		X	
	37. Increase > 100°F (56°C)		X	
	38. PWHT (T & T range)		X	
	39. T limits		X	
	40. Heat input		X	
	41. Current or polarity		X	
	42. I & E range		X	
	43. Stringer wave		X	
	44. Method (cleaning)		X	
	45. Method back gouge		X	
	46. Method to single pass/side		X	
	47. Method or automatic		X	
	48. Positioning		X	
QW-407 PWHT	49. PWHT (T & T range)		X	
	50. T limits		X	
	51. Heat input		X	
	52. Current or polarity		X	
	53. I & E range		X	
	54. Stringer wave		X	
	55. Method (cleaning)		X	
	56. Method back gouge		X	
	57. Method to single pass/side		X	
	58. Method or automatic		X	
	59. Positioning		X	
QW-410 Technique	60. Positioning		X	
	61. Method or automatic		X	
	62. Method to single pass/side		X	
	63. Method back gouge		X	
	64. Method (cleaning)		X	
	65. Stringer wave		X	
	66. I & E range		X	
	67. Current or polarity		X	
	68. Heat input		X	
	69. PWHT (T & T range)		X	
	70. T limits		X	
	71. Heat input		X	
	72. Current or polarity		X	
	73. I & E range		X	
	74. Stringer wave		X	
	75. Method (cleaning)		X	
	76. Method back gouge		X	
	77. Method to single pass/side		X	
	78. Method or automatic		X	
	79. Positioning		X	
	80. Positioning		X	
	81. Method or automatic		X	
	82. Method to single pass/side		X	
	83. Method back gouge		X	
	84. Method (cleaning)		X	
	85. Stringer wave		X	
	86. I & E range		X	
	87. Current or polarity		X	
	88. Heat input		X	
	89. PWHT (T & T range)		X	
	90. T limits		X	
	91. Heat input		X	
	92. Current or polarity		X	
	93. I & E range		X	
	94. Stringer wave		X	
	95. Method (cleaning)		X	
	96. Method back gouge		X	
	97. Method to single pass/side		X	
	98. Method or automatic		X	
	99. Positioning		X	
	100. Positioning		X	
	101. Method or automatic		X	
	102. Method to single pass/side		X	
	103. Method back gouge		X	
	104. Method (cleaning)		X	
	105. Stringer wave		X	
	106. I & E range		X	
	107. Current or polarity		X	
	108. Heat input		X	
	109. PWHT (T & T range)		X	
	110. T limits		X	
	111. Heat input		X	
	112. Current or polarity		X	
	113. I & E range		X	
	114. Stringer wave		X	
	115. Method (cleaning)		X	
	116. Method back gouge		X	
	117. Method to single pass/side		X	
	118. Method or automatic		X	
	119. Positioning		X	
	120. Positioning		X	
	121. Method or automatic		X	
	122. Method to single pass/side		X	
	123. Method back gouge		X	
	124. Method (cleaning)		X	
	125. Stringer wave		X	
	126. I & E range		X	
	127. Current or polarity		X	
	128. Heat input		X	
	129. PWHT (T & T range)		X	
	130. T limits		X	
	131. Heat input		X	
	132. Current or polarity		X	
	133. I & E range		X	
	134. Stringer wave		X	
	135. Method (cleaning)		X	
	136. Method back gouge		X	
	137. Method to single pass/side		X	
	138. Method or automatic		X	
	139. Positioning		X	
	140. Positioning		X	
	141. Method or automatic		X	
	142. Method to single pass/side		X	
	143. Method back gouge		X	
	144. Method (cleaning)		X	
	145. Stringer wave		X	
	146. I & E range		X	
	147. Current or polarity		X	
	148. Heat input		X	
	149. PWHT (T & T range)		X	
	150. T limits		X	
	151. Heat input		X	
	152. Current or polarity		X	
	153. I & E range		X	
	154. Stringer wave		X	
	155. Method (cleaning)		X	
	156. Method back gouge		X	
	157. Method to single pass/side		X	
	158. Method or automatic		X	
	159. Positioning		X	
	160. Positioning		X	
	161. Method or automatic		X	
	162. Method to single pass/side		X	
	163. Method back gouge		X	
	164. Method (cleaning)		X	
	165. Stringer wave		X	
	166. I & E range		X	
	167. Current or polarity		X	
	168. Heat input		X	
	169. PWHT (T & T range)		X	
	170. T limits		X	
	171. Heat input		X	
	172. Current or polarity		X	
	173. I & E range		X	
	174. Stringer wave		X	
	175. Method (cleaning)		X	
	176. Method back gouge		X	
	177. Method to single pass/side		X	
	178. Method or automatic		X	
	179. Positioning		X	
	180. Positioning		X	
	181. Method or automatic		X	
	182. Method to single pass/side		X	
	183. Method back gouge		X	
	184. Method (cleaning)		X	
	185. Stringer wave		X	
	186. I & E range		X	
	187. Current or polarity		X	
	188. Heat input		X	
	189. PWHT (T & T range)		X	
	190. T limits		X	
	191. Heat input		X	
	192. Current or polarity		X	
	193. I & E range		X	
	194. Stringer wave		X	
	195. Method (cleaning)		X	
	196. Method back gouge		X	
	197. Method to single pass/side		X	
	198. Method or automatic		X	
	199. Positioning		X	
	200. Positioning		X	
	201. Method or automatic		X	
	202. Method to single pass/side		X	
	203. Method back gouge		X	
	204. Method (cleaning)		X	
	205. Stringer wave		X	
	206. I & E range		X	
	207. Current or polarity		X	
	208. Heat input		X	
	209. PWHT (T & T range)		X	
	210. T limits		X	
	211. Heat input		X	
	212. Current or polarity		X	
	213. I & E range		X	
	214. Stringer wave		X	
	215. Method (cleaning)		X	
	216. Method back gouge		X	
	217. Method to single pass/side		X	
	218. Method or automatic		X	
	219. Positioning		X	
	220. Positioning		X	
	221. Method or automatic		X	
	222. Method to single pass/side		X	
	223. Method back gouge		X	
	224. Method (cleaning)		X	
	225. Stringer wave		X	
	226. I & E range		X	
	227. Current or polarity		X	
	228. Heat input		X	
	229. PWHT (T & T range)		X	
	230. T limits		X	
	231. Heat input		X	
	232. Current or polarity		X	
	233. I & E range		X	
	234. Stringer wave		X	
	235. Method (cleaning)		X	
	236. Method back gouge		X	
	237. Method to single pass/side		X	
	238. Method or automatic		X	
	239. Positioning		X	
	240. Positioning		X	
	241. Method or automatic		X	
	242. Method to single pass/side		X	
	243. Method back gouge		X	
	244. Method (cleaning)		X	
	245. Stringer wave		X	
	246. I & E range		X	
	247. Current or polarity		X	
	248. Heat input		X	
	249. PWHT (T & T range)		X	
	250. T limits		X	
	251. Heat input		X	
	252. Current or polarity		X	
	253. I & E range		X	
	254. Stringer wave		X	
	255. Method (cleaning)		X	
	256. Method back gouge		X	
	257. Method to single pass/side		X	
	258. Method or automatic		X	
	259. Positioning		X	
	260. Positioning		X	
	261. Method or automatic		X	
	262. Method to single pass/side		X	
	263. Method back gouge		X	
	264. Method (cleaning)		X	
	265. Stringer wave		X	
	266. I & E range		X	
	267. Current or polarity		X	
	268. Heat input		X	
	269. PWHT (T & T range)		X	
	270. T limits		X	
	271. Heat input		X	
	272. Current or polarity		X	
	273. I & E range		X	
	274. Stringer wave		X	
	275. Method (cleaning)		X	
	276. Method back gouge		X	
	277. Method to single pass/side		X	
	278. Method or automatic		X	
	279. Positioning		X	
	280. Positioning		X	
	281. Method or automatic		X	
	282. Method to single pass/side		X	
	283. Method back gouge		X	
	284. Method (cleaning)		X	
	285. Stringer wave		X	
	286. I & E range		X	
	287. Current or polarity		X	
	288. Heat input		X	
	289. PWHT (T & T range)		X	
	290. T limits		X	
	291. Heat input		X	
	292. Current or polarity		X	
	293. I & E range		X	
	294. Stringer wave		X	
	295. Method (cleaning)		X	
	296. Method back gouge		X	
	297. Method to single pass/side		X	
	298. Method or automatic		X	
	299. Positioning		X	
	300. Positioning		X	
	301. Method or automatic		X	
	302. Method to single pass/side		X	
	303. Method back gouge		X	
	304. Method (cleaning)		X	
	305. Stringer wave		X	
	306. I & E range		X	
	307. Current or polarity		X	
	308. Heat input		X	
	309. PWHT (T & T range)		X	
	310. T limits		X	
	311. Heat input		X	
	312. Current or polarity		X	
	313. I & E range		X	
	314. Stringer wave		X	
	315. Method (cleaning)		X	
	316. Method back gouge		X	
	317. Method to single pass/side		X	
	318. Method or automatic		X	
	319. Positioning		X	
	320. Positioning		X	
	321. Method or automatic		X	
	322. Method to single pass/side		X	
	323. Method back gouge		X	
	324. Method (cleaning)		X	
	325. Stringer wave		X	
	326. I & E range		X	
	327. Current or polarity		X	
	328. Heat input		X	
	329. PWHT (T & T range)		X	
	330. T limits		X	
	331. Heat input		X	
	332. Current or polarity		X	
	333. I & E range		X	
	334. Stringer wave		X	
	335. Method (cleaning)		X	
	336. Method back gouge		X	
	337. Method to single pass/side		X	
	338. Method or automatic		X	
	339. Positioning		X	
	340. Positioning		X	
	341. Method or automatic		X	
	342. Method to single pass/side		X	
	343. Method back gouge			

QW-403.6

- Minimum B.M. thickness qualified is : T or 16 mm whichever is less
- When  $T < 6$  mm , Minimum thickness qualified is  $1/2T$

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QW-403.5


- WPS shall be qualified using one of the following
  - Same B.M. to be used in production welding
  - B.M. listed in the same P-Number group no in QW-422 as the B.M. to be used in production welding
  - When B.M. of different P-Number group number combinations are qualified using a single test coupon, that coupon qualifies the welding of those two P-Number Group number to them selves as well as to each other using the variable qualified.

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<div data-bbox="1248 1854 1321 1926" data-label="Image"> </div> <div data-bbox="601 1854 1054 1901" data-label="Text"> <p>QW-404.4 &amp; QW-404.5</p> </div>	<div data-bbox="434 1238 453 1256" data-label="Text"> <p>21</p> </div> <ul style="list-style-type: none"> <li>• A change from one F-Number in QW-432 to any other F-Number or to any other filler metal not listed in table QW-432.</li> <li>• Change fro one A-Number to any other A-Number in table QW-442</li> <li>• Qualification with A-No 1 shall qualify for A-No.2 &amp; vice versa.</li> </ul>
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<div data-bbox="1248 949 1321 1021" data-label="Image"> </div> <div data-bbox="727 949 932 994" data-label="Text"> <p>QW-405.2</p> </div>	<div data-bbox="434 333 453 351" data-label="Text"> <p>22</p> </div> <ul style="list-style-type: none"> <li>• A change from any position to the vertical uphill progression</li> <li>• Vertical uphill progression shall qualifies for all position</li> <li>• In uphill progression, a change from stringer bead to weave bead.</li> </ul>
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**QW-407.2**

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- Procedure qualification test shall be subjected to PWHT essentially equivalent to that encountered in the fabrication of production weld, including at least 80% of the aggregate times at temperature.




**QW-406.1 & QW 406.3**

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- QW-406.1
  - Decrease of more than 55° C in the preheat temperature qualified. Minimum temperature of welding shall be specified in WPS.
- QW-406.3
  - Increase of more than 55° C in the maximum interpass temperature recorded on the PQR


QW-409.1

- Increase in heat input, or an increase in volume of weld metal deposited per unit length of weld, over that qualified.
- Heat Input =  $\frac{\text{Voltage} \times \text{Amperage} \times 60}{\text{Travel Speed (in./min(mm/min.))}}$  (J/in. (J/mm))
- Volume of weld metal measured by :
  - 1 Increase in bead size(W X T)
  - 2 Decrease in length of weld bead per unit length of electrode.


QW-255

Welding Variables Procedure  
Specification(WPS)

GMAW & FCAW

if  $T < 13$  then max<sup>n</sup> qualified thickness will be 1.17

changes in P-No SA to P-No SB on SC is essential & avoidable.

As - Penetration Restricted. (C2 - max penetration)

mode of metal transfer in GMAW affect by gas type.

Paragraph	Brief of Variables	Essential	Supplementary	Nonessential
QW-402 Joints	1. Groove design 4. Backing 10. Root spacing 11. Retainers 5. Group Number 7. Limits		X	X
QW-403 Base Metals	6. T Limits 7. T Limits > 8 in. (203 mm) 8. T qualified 9. T Pass > 1/2 in. (13 mm) 10. T Limits (S, C, R, Arc) 11. P-No. qualified 13. P-No. 5/9/10	X		
QW-404 Filler Metals	4. F-Number 5. A-Number 6. Diameter 12. AWS class. 23. Filler metal product form 24. Supplemental 27. Alloy elements 30. T 32. T Limits (S, C, R, Arc) 33. AWS Class.	X	X	X
QW-405 Positions	1. Position 2. Position 3. T1 Vertical welding		X	X
QW-406 Preheat	1. Decrease > 100°F (56°C) 2. Preheat main. 3. Increase > 100°F (56°C) (IP)	X		X
QW-407 PWHT	1. PWHT 2. PWHT (T & T range) 4. T Limits	X	X	


→ Titanium = 250°C below it is reactive & trailing gas is used to prevent oxidation up to shield & shield gas get supplied.

Paragraph	Brief of Variables	Essential	Supplementary	Nonessential
QW-408 Gas	1. Trail or comp. 2. Single, mixture, or % 3. Flow rate 5. Backing or comp. 9. Shielding or trailing 10. Heat input	X		X
QW-409 Electrical Characteristics	1. Heat input 2. Transfer mode 4. Current or polarity 8. I & E range		X	X
QW-410 Technique	.1. String/weave .3. Orifice, cup, or nozzle size .5. Method cleaning .6. Method back gouge .7. Oscillation .8. Tube-work distance 9. Multi to single pass/side 10. Single to multi electrodes 15. Electrode spacing 25. Manual or automatic 26. Peening		X	X

Legend:  
+ Addition  
- Deletion  
> Increase/greater than  
< Decrease/less than  
↑ Uphill  
↓ Downhill  
→ Forehand  
← Backhand  
φ Change

GMAW/  
FCAW





# QW-254

## Welding Variables Procedure Specification (WPS)

### SAW

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Paragraph	Brief of Variables			
QW-402 Joints	1. Groove design	Essential	Essential	Nonessential
	2. Backing			
	3. Root spacing			
	4. Retainers			
	5. Group Number			
QW-403 Base Metals	6. T Limits			
	7. T Limits $\geq 8$ in. (203 mm)			
	8. T qualified			
	9. T Pass $\geq 1/2$ in. (13 mm)			
	10. P-No. qualified			
	11. P-No. 5/9/10			
	12. F-Number			
	13. A-Number			
	14. Diameter			
QW-404 Filler Metals	15. Flux/wire class.			
	16. Alloy flux			
	17. Supplemental			
	18. Alloy elements			
	19. Flux designation			
	20. AWS class.			
	21. Flux type			
	22. Flux/wire class.			
QW-405 Positions	23. Position			
	24. Decrease $\geq 100^{\circ}\text{F}$ (56 $^{\circ}\text{C}$ )			
	25. Preheat main.			
	26. Increase $\geq 100^{\circ}\text{F}$ (56 $^{\circ}\text{C}$ ) (1P)			
QW-407 PWHT	27. PWHT (T & T range)			
	28. T Limits			
QW-409 Electrical Characteristics	29. Heat input			
	30. Current or polarity			
	31. I & E range			



Legend:			
+ Addition	> Increase/greater than	↑ Uphill	→ Forehand
- Deletion	< Decrease/less than	↓ Downhill	← Backhand
ϕ Change			
GTAW			
Paragraph	Brief of Variables	Essential	Supplementary
QW-409 Electrical Characteristics	.1 > Heat Input		X
	.3 ± Pulsing I		
	.4 ϕ Current or polarity		X
	.8 ϕ I & E range		X
QW-410 Technique	.12 ϕ Tungsten electrode		X
	.1 ϕ String/weave		X
	.3 ϕ Orifice, cup, or nozzle size		X
	.5 ϕ Method cleaning		X
	.6 ϕ Method back gouge		X
	.7 ϕ Oscillation		X
	.9 ϕ Multi to single pass/side		X
	.10 ϕ Single to multi electrodes		X
	.11 ϕ Closed to out chamber	X	
	.15 ϕ Electrode spacing		X
	.25 ϕ Manual or automatic		X
	.26 ± Peening		X

Paragraph	Brief of Variables	Essential	Supplementary	Nonessential
QW-402 Joints	.1 ϕ Groove design			X
	.5 + Backing			X
	.10 ϕ Root spacing			X
	.11 = Retainers			X
QW-403 Base Metals	.5 ϕ Group Number		X	
	.6 T Limits			
	.7 T Limits ≥ 6 in. (203 mm)	X		
	.8 T Qualified	X		
QW-404 Filler Metals	.13 ϕ P-No. 5/9/10	X		
	.3 ϕ Size	X		X
	.4 ϕ F-Number	X		
	.5 ϕ A-Number	X		
QW-405 Positions	.12 ϕ AWS class		X	
	.14 = Filler			
	.22 = Consum. insert	X		
	.23 ϕ Filler metal product form	X		
QW-406 Preheat	.30 ϕ T			
	.33 ϕ AWS class			
	.50 = Flux			
	.1 + Position			
QW-407 PWHT	.1 ϕ PWHT	X		
	.2 ϕ PWHT (T & T range)	X		
	.4 T Limits			
	.1 ± Trail or ϕ comp.			
QW-408 Gas	.1 ϕ Shielding or trailing	X		
	.2 ϕ Single, mixture, or %	X		
	.3 ϕ Flow rate			
	.5 = or ϕ Backing flow			

P – Number Grouping (Base Metal For Qualification)				
• QW-422				
P-No	Group No	Met. Spec.	Grade	Met. Quality & Form
P3	2	SA 302	A	Mn – 0.5 Mo – Plate
P3	3	SA 302	B,C,D	Mn – 0.5 Mo – Plate
P3	1	SA 335	P1 / P2	C – 0.5 Mo – Pipe
P3	3	SA 533	TP-B, Cl-1 or 2	C – 0.5 Mo – Plate
P3	1	SA 209	T1, T1a, T1b	C – 0.5 Mo – Tube
P3	2	SA 282	F1	C – 0.5 Mo – Forging

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P – Number Grouping (Base Metal For Qualification)				
• QW-422				
P-No	Group No	Met. Spec.	Grade	Met. Quality & Form
P1	1	SA 515 / SA 516	60	CS – Plate
P1	2	SA 515 / SA 516	70	CS – Plate
P1	1	SA 106	A/B	CS – Pipe
P1	2	SA 106	C	CS – Pipe
P1	1	SA 333	6	CS – Pipe
P1	3	SA 333	10	CS – Pipe
P1	1	SA 234	WPB	CS Pipe Fitting
P1	2	SA 234	WPC	CS Pipe Fitting
P1	1	SA 285	C / B	CS Plate
P1	1	SA 179	---	CS Tube
P1	1	SA 105	---	CS Forging
P1	2	SA 181	CI 70	CS Forging

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P – Number Grouping (Base Metal For Qualification)					
• QW-422					
P- No	Group No	Met. Spec.	Grade	Met. Quality & Form	
P4	1	SA 387	12, CI-1/2	1Cr, 0.5 Mo – Plate	
P4	3	SA 387	11, CI-1/2	1.25 Cr, 0.5 Mo – Plate	
P4	1	SA 335	P12/P11	1Cr (1.25 Cr) – 0.5 Mo – Pipe	
P4	2	SA 423	TP - 1/2	1.25 Cr, 0.5 Mo – Tube	
P4	1	SA 282	F12, CI-1/2	1. Cr – 0.5 Mo – Forging	
P4	1	SA 336	F11, CI-1/2/3	1.25 Cr – 0.5 Mo – Forging	

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P – Number Grouping (Base Metal For Qualification)					
• QW-422					
P- No	Group No	Met. Spec.	Grade	Met. Quality & Form	
P5A	1	SA 387	22, CI-1/2	2.25 Cr, 1 Mo – Plate	
P5B	1	SA 387	5, CI-2	5 Cr, 0.5 Mo – Plates	
P5A	1	SA 335	P22	2.25 Cr, 1 Mo – Pipe	
P5A	1	SA 213	TP - 22	2.25 Cr, 1 Mo – Tube	
P5B	1	SA 182	F5	5 Cr – 0.5 Mo – Forging	
P5C	1	SA 182	F22V	2.25 Cr – 1 Mo, V – Forging	
P5A	1	SA 336	F22, CI-1/3	2.25 Cr – 1 Mo – Forging	

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P – Number Grouping (Base Metal For Qualification)				
• QW-422				
P-No	Group No	Met. Spec.	Grade	Met. Quality & Form
P8	1	SA 312	TP321	18Cr, 10Ni, Ti - Pipe
P8	1	SA 312	TP347	18Cr, 10Ni, Nb - Pipe
P8	1	SA 336	TP316	18Cr, 8 Ni, 2Mo - Forging
P8	1	SA 240	TP304	18Cr, 8Ni - Plates
P8	2	SA 204	TP309S	23Cr, 12Cr - Plates
P8	1	SA 249	TP317	18Cr, 13Ni, 3Mo - Tube
P8	1	SA 249	TP316L	16Cr, 12Ni, 2Mo - Tube

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P – Number Grouping (Base Metal For Qualification)				
• QW-422				
P-No	Group No	Met. Spec.	Grade	Met. Quality & Form
P6	2	SA 240	TP 429	15Cr - Plate
P6	4	SA 731	S41500	13Cr, 4.5 Ni, Mo - Pipe
P6	1	SA 268	TP410	13Cr - Tube
P6	3	SA 336	F6	13Cr - Forging
P7	2	SA182	F430	17Cr - Forging
P7	2	SA 240	TP 430	17Cr - Plate
P7	2	SA 268	TP430	17Cr - Tube
P7	2	SA 731	TP439	18Cr, Ti - Pipe

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P – Number Grouping (Base Metal For Qualification)				
• QW-422				
P-No	Group No	Met. Spec.	Grade	Met. Quality & Form
P9B	1	SA 333	3	3.5Ni - Pipe
P9A	1	SA334	7	2.5Ni - Tube
P9A	1	SA 350	LF5, Cl. 2	1.5Ni - Forging
P9B	1	SA 350	LF3	3.5Ni - Forging
P9A	1	SA 203	A	2.5Ni - Plate
P9B	1	SA 203	E	3.3Ni - Plate

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P – Number Grouping (Base Metal For Qualification)				
• QW-422				
P-No	Group No	Met. Spec.	Grade	Met. Quality & Form
P11A	1	SA 333	8	9Ni - Pipe
P11A	1	SA334	8	9Ni - Tube
P11A	5	SA 508	4N, Cl. 2	3.5Ni - 1.75 Cr - 0.5Mo - V, Forging
P11A	5	SA 508	5, Cl. 2	3.5Ni - 1.75 Cr - 0.5Mo - V, Forging
P11A	4	SA 533	TP B, Cl. 3	Mn, 0.5 Mo, 0.5Ni - Plate
P11A	4	SA 533	TP C, Cl. 3	Mn, 0.5 Mo, 0.75Ni - Plate

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## Welding Procedure Qualification

### Material Grouping(P-Numbers)

Base Metal	Welding	Brazing
Steel and steel alloys	P-No. 1 through P-No. 11 incl. P-No. 5A, 5B, and 5C	P-No. 101 through P-No. 103
Aluminum and aluminum-base alloys	P-No. 21 through P-No. 25	P-No. 104 and P-No. 105
Copper and copper-base alloys	P-No. 31 through P-No. 35	P-No. 107 and P-No. 108
Nickel and nickel-base alloys	P-No. 41 through P-No. 47	P-No. 110 through P-No. 112
Titanium and titanium-base alloys	P-No. 51 through P-No. 53	P-No. 115
Zirconium and zirconium-base alloys	P-No. 61 through P-No. 62	P-No. 117

## Welding Procedure Qualification

QW-424

### Base Metal(s) Used for Procedure Qualification Coupon

One metal from a P-Number to any metal from the same P-Number  
 One metal from a P-Number to any metal from any other P-Number  
 One metal from P-No. 3 to any metal from P-No. 3  
 One metal from P-No. 4 to any metal from P-No. 4  
 One metal from P-No. 5A to any metal from P-No. 5A  
 One metal from P-No. 5A to a metal from P-No. 4, or P-No. 3, or P-No. 1  
 One metal from P-No. 4 to a metal from P-No. 3 or P-No. 1  
 Any unassigned metal to the same unassigned metal  
 Any unassigned metal to any P-Number metal  
 Any unassigned metal to any other unassigned metal

### Base Metals Qualified

Any metals assigned that P-Number  
 Any metal assigned the first P-Number to any metal assigned the second P-Number  
 Any P-No. 3 metal to any metal from P-No. 3 or P-No. 1  
 Any P-No. 4 metal to any metal from P-No. 4, 3, or 1  
 Any P-No. 5A metal to any metal from P-No. 5A, 4, 3, or 1 metals  
 Any P-No. 5A metal to any metal assigned to P-No. 4, or P-No. 3, or P-No. 1  
 Any P-No. 4 metal to any metal assigned to P-No. 3 or P-No. 1  
 The unassigned metal to itself  
 The unassigned metal to any metal assigned to the same P-Number as the qualified metal  
 The first unassigned metal to the second unassigned metal



# Welding Procedure Qualification



## Important F-NUMBERS

F-No.	ASME Specification	AWS Classification
4	SFA-5.1	EXX15
4	SFA-5.1	EXX16
4	SFA-5.1	EXX18
4	SFA-5.1	EXX18M
4	SFA-5.1	EXX48
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-15
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-16
4	SFA-5.4 other than austenitic and duplex	EXXX(X)-17

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# Welding Procedure Qualification



## Grouping of Electrodes and Welding Rods for Qualification

F-No.	ASME Specification	AWS Classification
5	SFA-5.4 austenitic and duplex	EXXX(X)-15
5	SFA-5.4 austenitic and duplex	EXXX(X)-16
5	SFA-5.4 austenitic and duplex	EXXX(X)-17

## Grouping of Electrodes and Welding Rods for Qualification

F-No.	ASME Specification	AWS Classification
43	SFA-5.11	ENICrFe-1
43	SFA-5.11	ENICrFe-2
43	SFA-5.11	ENICrFe-3
43	SFA-5.11	ENICrFe-4
43	SFA-5.11	ENICrFe-7
43	SFA-5.11	ENICrFe-9
43	SFA-5.11	ENICrFe-10
43	SFA-5.11	ENICrMo-2
43	SFA-5.11	ENICrMo-3
43	SFA-5.11	ENICrMo-6
43	SFA-5.11	ENICrMo-12

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Welding Procedure Qualification	
A-NUMBERS	
Classification of Ferrous Weld Metal Analysis for Procedure Qualification	
Analysis, % [Note (1)]	
A-No.	Types of Weld Deposit
C	Cr
Mn	Mo
Si	Ni
1	Mild Steel
2	Carbon-Molybdenum
3	Chrome (0.4 to 2%) -Molybdenum
4	Chrome (2% to 6%) -Molybdenum
5	Chrome (6% to 10.5%) -Molybdenum
6	Chrome-Martensitic
7	Chrome-Ferritic
8	Chromium-Nickel
9	Chromium-Nickel
10	Nickel to 4%
11	Manganese-Molybdenum
12	Nickel-Chrome - Molybdenum

NOTE: (1) Single values shown above are maximum.

## How To Qualify Groove Butt Weld Procedure?



### 3) Write A Welding Procedure Specification -WPS

- WPS Provides Direction for A Specific Welding
- WPS Shall Include All Essential, Supplementary Essential & Non Essential Variables
- WPS Format Available in ASME Sec. IX.
- Each WPS Shall be Assigned with A Unique Number.

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## How To Qualify Groove Butt Weld Procedure?



### 4) Prepare A Test Coupon As Per WPS

- Coupon Size: 500 mm X 150 mm X T
- All Other Details as per Written WPS
- Complete the Welding by Reasonably Skilled Welder
- All Welding Variables Shall be Used Within the Limit Specified in WPS.
- All Variables Actually Used Shall be Documented as Annexure to PQR ( Procedure Qualification Record)

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## How To Qualify Groove Butt Weld Procedure?



### 5) NDT Of Weld Coupon – Optional

- X-Ray / Radiograph the Weld Joint ( Not a Code Requirement)
- Mark Transverse Tensile & Guided Bends As Per QW463
- Eliminate Defective Weld Portion If Any, While Marking the Test Specimens
- Preserve RT Report & X-Ray Film as Annexure to PQR

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## How To Qualify Groove Butt Weld Procedure?



### 6) Mechanical Tests

- QW451 Procedure Qualification Thickness Limits & Test Specimen

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GROOVE-WELD TENSION TESTS AND TRANSVERSE-BEND TESTS									
QW-451.1									
Type and Number of Tests Required									
(Tension and Groove-Bend Tests) (Note (2))									
<div> <div> <div>Range of Thickness <math>T</math> of Base Material</div> <div> <div>Qualified, in. (mm)</div> <div>[Notes (1) and (2)]</div> </div> </div> <div> <div>Max.</div> <div>Max.</div> </div> </div>									
<div> <div>Thickness <math>T</math> of Deposited Weld Metal</div> <div> <div>Qualified, in. (mm)</div> <div>[Notes (1) and (2)]</div> </div> </div> <div> <div>Tension</div> <div>QW-150</div> </div>									
<div> <div>Side Face Bend</div> <div>QW-160</div> </div> <div> <div>Root Bend</div> <div>QW-160</div> </div>									
Welded, in. (mm)									
Thickness $T$ of Test Coupon									
less than $\frac{1}{16}$ , (1.6)	$T$	2 T							
$\frac{1}{16}$ to $\frac{3}{16}$ , (1.6 to 10), incl.	$\frac{1}{16}$ (1.6)	2 T	2 T						
Over $\frac{3}{16}$ , (10), but less than $\frac{1}{2}$ , (19)	$\frac{3}{16}$ (4.8)	2 T	2 T						
$\frac{1}{2}$ , (19) to less than $1\frac{1}{2}$ , (38)	$\frac{1}{2}$ (12.5)	2 T	2 T						
$1\frac{1}{2}$ , (38) and over	$\frac{1}{2}$ (12.5)	2 T	2 T						





## QW-153 Acceptance Criteria - Tension Tests

Min. specified T.S. of base metal  
Min. specified T.S. of weaker of the two if base metal

- Min. specified T.S. of weaker of the two, if base metal of different min. T.S. are used.  
Min. specified T.S. of weld metal when applicable when the applicable section provides for the use of weld metal having lower room temp. strength than base metal.

If specimen breaks in the B.M. out side of the weld or weld interface, the test shall be accepted as meeting the requirements, provided the strength is not more than 5% below the minimum specified T.S. of the base metal

$T_f$ in. (mm)	$T_f$ in. (mm)
$\frac{1}{16} < T_f < \frac{1}{8}$ (3.2-6.3)	$\frac{1}{8}$ (3.2)
$\frac{1}{8} < T_f < \frac{3}{16}$ (3.2-4.8)	$\frac{3}{16}$ (4.8)
$\frac{3}{16} < T_f < \frac{1}{2}$ (4.8-12.7)	$\frac{1}{2}$ (12.7)



## How To Qualify Groove Butt Weld Procedure?



### QW-163 Acceptance Criteria - Bend Tests

- Guided bend test specimens shall have no open discontinuity in the weld or HAZ exceeding 3 mm, measured in any direction on the convex surface of the specimen after bending

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## How To Qualify Groove Butt Weld Procedure?



### 8) PQR – Procedure Qualification Record

- PQR Format Available in Sec. IX
- Record All Relevant Data in the Format.
- Record All Mechanical Test Results
- Attach All Test Reports & Welding Parameters Used as Annexure to PQR
- Assign Unique Number to Each PQR
- WPS No Shall be Referred in PQR

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*Thank You*

## Qualified WPS



- A WPS Remains Qualified When
  - A Procedure Qualification Coupon Is Welded As Per WPS
  - All Mechanical Tests of The Coupon Are Completed
  - All Test Results Are Within The Acceptable Limit
  - The Supporting PQR No Is Referred In The WPS

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Φ multipass do single pass essential (SAP)  
 multipass to single pass when we go then we need another PQR

